PB84-110147

Study of PCB Destruction Efficiency and Performance for a Coal-Fired Utility Boiler. Volume 1. Test and Evaluation

Versar, Inc., Springfield, VA

Prepared for

Industrial Environmental Research Lab.
Research Triangle Park, NC

Oct 83

U.S. Department of Commerce
National Technical Information Service
NTIS

PB84-110147

EPA-600/2-83-101a
October 1983

A STUDY OF PCB DESTRUCTION EFFICIENCY AND PERFORMANCE FOR A COAL-FIRED UTILITY BOILER

VOLUME 1: TEST AND EVALUATION

by

Frank C. Whitmore and James D. Barden
VERSAR INC.
6850 Versar Center
Springfield, Virginia 22151

Contract 68-02-3181

Project Officer - David C. Sanchez

Industrial Environmental Research Laboratory
Office of Environmental Engineering and Technology
Research Triangle Park, North Carolina 27711

U.S. Environmental Protection Agency
Office of Research and Development
Washington, D.C. 20460

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-600/2-83-101a		PB84 110147

4. TITLE AND SUBTITLE	5. REPORT DATE
A Study of PCB Destruction Efficiency and Performance for a Coal-fired Utility Boiler; Volume 1. Test and Evaluation	October 1983
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Frank C. Whitmore and James D. Barden	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Versar, Inc. 6850 Versar Center Springfield, Virginia 22151	11. CONTRACT/GRANT NO. 68-02-3181, Task 2
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
EPA, Office of Research and Development Industrial Environmental Research Laboratory Research Triangle Park, NC 27711	Task Final; 3/80 - 5/82 14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES IERL-RTP project officer is David C. Sanchez, Mail Drop 63, 919/541-2547.

16. ABSTRACT The report gives results of an evaluation of the adequacy of a large coal-fired utility boiler for disposal of oils containing 50-499 ppm of PCBs under conditions set by the PCB Disposal Regulations. TVA's Widows Creek Boiler No. 1 was used for the tests. In these tests, all effluent streams were sampled and analyzed, to determine representative values of Destruction Efficiency (DE) for this technology. The average PCB content of the oil used was 215 ppm. Test results indicated that, at the maximum contaminated oil feed rate of 454 L/min (120 gal./hr) utilized, boiler efficiency was not discernibly affected. Further, analyses showed that PCB levels were below laboratory-established detection limits. On the basis that both the flue gases and the fly ash could have contained PCB concentrations just below the quantifiable level, the minimum (worst case) DE can be determined. The average over six tests (two from each of three feed configurations) showed a DE of 99.95% which, since the actual concentrations of PCBs were probably significantly below the detection limits, appears to represent a minimum value for the DE in the system. Test results showed that the technology represented by Widows Creek Boiler No. 1 meets the stated requirements of a 99.9% DE for destruction of PCBs in waste oil in the 50-499 ppm range.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution Chlorine Aromatic Compounds Biphenyl Incinerators Utilities Boilers Coal Combustion Oils	Pollution Control Stationary Sources Polychlorinated Biphenyl Destruction Efficiency	13B 21D 07C 21B 11H

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Release to Public	Unclassified	79
	20. SECURITY CLASS (This page)	22. PRICE
	Unclassified	

EPA Form 2220-1 (9-73)

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

In the preparation of the PCB disposal regulations it was recognized that there existed a very large reservoir of PCB contaminated oils that possessed significant heating value and thus represented a valuable resource. With this recognition, it was ordered that such oils, with PCB contamination within the range of 50 to 500 ppm, could be used as fuel in high efficiency boilers. At the time of the issuance of these regulations there was limited experimental demonstration that such boilers could routinely attain the required destruction efficiency of 99.9%. The experiment that is reported herein was designed to determine the PCB destruction efficiency for a typical coal-fired utility power boiler operating under normal operating conditions in accordance with applicable State and Federal regulations. The results of this study verify the technical appropriateness of the use of power boilers for the effective destruction of low level PCB waste oils.

PREFACE

The PCB Disposal Regulations state that oils contaminated with PCBs in the concentration range from 50 to 500 ppm may be disposed of in high efficiency power boilers. Tests conducted previously on incineration of PCB-contaminated oil in a boiler fired by oil have shown that adequate destruction of PCBs is available from such a unit. This report describes similar tests on PCB destruction in a coal-fired utility boiler.

Since the destruction efficiency is defined in terms of the PCB content of all the effluent streams from the boiler, the coal-fired technology requires that account be taken of the fly ash as well as the flue gases. The fact that a PCB molecule attached to a fly ash particle could be protected from the high temperature environment requires that a test be conducted on a coal-fired power boiler under typical operating conditions.

Arrangements were made, through the mechanism of an Interagency Agreement between EPA and the Tennessee Valley Authority (TVA), to make available for the program a typical power boiler for a series of PCB-contaminated oil tests. Widows Creek Boiler Number One was selected as a suitable representative of such technology. The Widows Creek complex is located about 5 km south of the town of Bridgeport, Alabama, in a rural setting west of the Tennessee River.

ABSTRACT

The purpose of the program described herein was to evaluate a large coal-fired utility boiler as to its adequacy for disposal of PCB-contaminated oils containing 50-499 ppm of PCBs under the conditions set by the PCB Disposal Regulations. A TVA boiler, Widows Creek Boiler Number One, was selected as the unit to be used. In these tests, all effluent streams were sampled and analyzed, in order to permit determination of representative values of Destruction Efficiency (DE) for this type of technology. The average PCB content of the oil used was 215 ppm.

The permitting process required that permits and approvals be obtained from EPA Region IV, from the State of Alabama and from TVA. The process was simplified through the preparation and use of a detailed protocol that treated each detail of the proposed experiments and the environmental impact of each phase of the program. After the required public hearing in Bridgeport, Alabama, the State of Alabama issued a permit for the test burns that allowed a thirty (30) day period for the completion of the tests.

After a series of background measurements that also allowed the determination of the rate of production of fly ash, a series of three PCB-injection experiments were carried out. The configuration of Unit Number One is such that the fire box is divided into two regions by a series of water tubes running vertically through the fire box. This results in separation of the flue gases into two separate streams, referred to as the A and the B side. With this physical arrangement, it proved possible to feed on one side of the boiler and use fly ash and flue gas samples from the other side as background. The three experiments were as follows:

1. Feed on A side, sample on both sides
2. Feed on B side, sample both sides
3. Feed on both sides, sample both sides.

The flue gases, the fly ash and the PCB-contaminated feed stock were all sampled for each test run. The flue gas samples were taken downstream of the electrostatic precipitators. Each experiment lasted for sufficient time to allow two samples to be taken on each of the plenums.

The results of these experiments indicated that, at the maximum contaminated oil feed rate of 454 l/min (120 gal/hr) utilized, there was no discernable effect on boiler efficiency. Further, analysis for PCB levels showed that the levels of PCBs were below the detection limits that had been established in the laboratory.

On the basis that both the flue gases and the fly ash could have contained PCB concentrations just below the quantifiable level, the minimum (worst-case) destruction efficiency can be determined. The average over six experiments (two from each configuration of the feed) showed a DE of 99.95% which, since the actual concentrations of PCBs were probably significantly below the detection limits, does appear to represent a minimum value for the DE in the system. The results of this experiment clearly demonstrate that the technology represented by Widows Creek Boiler Number One meets the stated requirements of a 99.9% DE for destruction of PCBs in waste oil in the 50 to 499 ppm range.

This report was submitted in fulfillment of Task 2, Contract No. 68-02-3181. This report covers the period 3/24/80 to 5/30/82, and work was completed as of 4/30/82.

CONTENTS

Foreword iii

Preface. iv

Abstract v

Figures viii

Tables ix

Acknowledgments. xi

1. Introduction. 1
   Permitting Activities 2
2. Conclusions 3
3. Experimental Design 4
   Widows Creek Number One Boiler. 6
   PCB Feed System 9
   PCB-Contaminated Oil. 11
   Sampling. 12
4. Experimental Data. 18
   Boiler Operational Data 18
   Flue Gas Data 23
   PCB Concentrations. 25
5. Calculations and Results 26
   Effect of PCB Feed on Boiler Efficiency 26
   Fly Ash/Bottom Ash Production Rates 27
   Destruction Efficiency (DE) 28
   Sensitivity Analysis. 32
   PCBs in Bottom Ash. 33
6. Bibliography 34

Appendix A - Air Sampling Data 35

Appendix B - Final Analytical Report 37

Appendix C - TVA 7287 Line Data. 65

FIGURES

Number		Page
1	Boiler Units One Through Six.	7
2	Schematic of Widows Creek Boiler Number One	8
3	Schematic of PCB-Contamination Oil Feed System.	10
4	Measured Temperature Distribution in Duct at Points S4 and S4' on Figure 2	14
5	Velocity Profile at Points S4 and S4' on Figure 2	15
6	Encapsulated PCB Sampling Train	16
7	Unit One Performance Data During Background Experiment. . . .	19
8	Unit One Performance Data During Experiment No. 1	20
9	Unit One Performance Data During Experiment No. 2	21
10	Unit One Performance Data During Experiment No. 3	22
B-1	PCB-1254 Standard 2ul Injection of 0.1 ppm	55
B-2	Typical Chromatogram of Impinger Samples	56
B-3	Fly Ash Standard 0.5 ppm 1254	61
B-4	Fly Ash Sample #315Y	62

TABLES

Number		Page
1	Variances in Experimental Design	5
2	Physical Data on Widows Creek Boiler Number One	9
3	Summary of Stack Sampling Data	24
4	Fly Ash Production Rate	23
5	Boiler Efficiency in Absence of PCB Feed	26
6	Boiler Efficiency in Presence of PCB Feed	27
7	Boiler Parameters	27
8	PCB Feed Rate	29
9	Estimated Total Fly Ash Production Rate	29
10	Estimated Fly Ash Production Rate - A and B Streams	30
11	Maximum PCB Emission Rate Associated with Fly Ash	30
12	Maximum PCB Emission in Effluent Gases	31
13	Minimum DE Considering Flue Gases and Fly Ash	31
14	Values of DE Considering only Fly Ash	32
B-1	Samples Received on December 2, 1981, for TVA Project 583.2	38
B-2	Actual Samples Analyzed	40
B-3	Detection Limits Per Matrix	41
B-4	Compositing of Flyash	45
B-5	GC/EC Analytical Conditions	48
B-6	Capillary GC/EC Analytical Conditions	49
B-7	Analytical Results and QC for Oil Samples	52
B-8	Density of Oil Samples	53

TABLES (Con't)

Number		Page
B-9	Analytical Results and QC for RAC Samples	54
B-10	Analytical Results and QC for Probe Washings.	57
B-11	Results of Recovery Study	59
B-12	Analytical Results and QC for Flyash Samples	60
B-13	Results for Determination of Flyash and Filter Weights	64

ACKNOWLEDGEMENTS

It is with great pleasure that we thank Ward Filgo and Al Price of TVA for their consistent help and support in the planning and carrying out of the program. We are particularly grateful to James Cooper and Sue Robertson of the Alabama Air Pollution Control Board for their patience in establishing a permit window that took into account the frailties of equipment and people. Finally, the unfailing patience and consistent guidance of David Sanchez and Glenn Kuntz of the Environmental Protection Agency were instrumental in the completion of this work.

SECTION 1

INTRODUCTION

The regulations that control the disposal of PCBs and PCB-contaminated materials[1] make a distinction between the required disposal procedures according to the PCB concentration. Those materials containing more than 500 ppm of PCBs must be disposed of in an incinerator that has been specifically tested for its ability to dispose of PCBs. On the other hand, those materials that contain less than 50 ppm of PCBs may be used as conventional fuels in boilers. The class of high heating value materials (such as used transformer oil, etc.) that exhibit PCB concentrations between 50 and 500 ppm of PCBs can only be burned in high efficiency power boilers (or in PCB incinerators). It has been a matter of some concern that the ability of such high efficiency boilers to produce acceptable destruction efficiencies (DE) be determined in representative systems. The report that follows will discuss a series of tests on a coal-fired boiler which addresses this concern.

Tests performed on several oil-fired power boilers[2,3] have shown that a DE of greater than 99.9% (as required by the regulations) can be obtained without degrading boiler performance. There is, however, a significant difference between an oil-fired boiler and one that is coal-fired. In the former case, the non-combustible component of the fuel is relatively small, so that the particulate components of the combustion gases represent an insignificant contribution. On the other hand, in a coal-fired boiler, there is a significant non-combustible (ash) content that is often as high as 15%. There is, then, the possibility that PCBs attached to the fly ash can survive passage through the high temperature regions of the boiler resulting in unacceptable DE values. It was the purpose of the experiments reported herein to investigate this possibility in a representative coal-fired system.

PERMITTING ACTIVITIES

After preliminary discussions the Tennessee Valley Authority (TVA) agreed to make available for this program one of their coal-fired boilers at the Widows Creek Station near Bridgeport, Alabama. Since this program was carried out under contract with the Environmental Protection Agency(EPA) at a TVA facility located in EPA Region IV and in the State of Alabama, there were a number of activities that preceded the actual carrying out of the experiments. Initially, permission for the planned experiments was discussed with the EPA regional office in Atlanta, Georgia. In response to a request from that office, a detailed protocol for the proposed experiments was prepared and presented to EPA Region IV, to TVA and to the Alabama Air Pollution Control Commission. After several meetings to clarify the protocol, permission was formally granted pending the signing of a suitable Interagency Agreement between TVA and EPA and pending the establishment of the areas of responsibility that each agency could assume.

After a period of negotiation, the required agreement was executed and, in accordance with Alabama law, a public hearing was announced in Bridgeport, Alabama. This meeting, with limited attendance by the public, raised no objection to the proposed permitting action. As a result, Alabama officials issued a thirty day permit for the conduct of the experiments at Widows Creek. The officials of Alabama were very understanding in changing the effective dates of the permit, since the tests were rescheduled several times due to periods of boiler shutdown during the summer and fall in 1981. The actual experiments were conducted on November 10-13, 1981 with observers present from EPA Region IV, TVA and Alabama as well as the sponsoring agency, EPA/IERL.

SECTION 2

CONCLUSIONS

The conclusions that can be drawn from these experiments are as follows:

1. A coal-fired power boiler can effectively destroy low level PCB-containing waste with no compromise in boiler performance.
2. The costs associated with such disposal should be minimal; in fact, such a disposal option should result in a significant savings over other options.
3. Disposal operations can be carried out with minimal risk to personnel or facility.

SECTION 3

EXPERIMENTAL DESIGN

The experiments described here have been designed to determine the destruction efficiency of a coal-fired power boiler in destroying PCB-contaminated oils under normal operating conditions for the boiler. Such experiments should, in order to reflect real-world conditions, be conducted on a boiler while it is on-line and thereby experiencing the variations in the demand that are normal for such a system. In the original conception of these experiments it was planned that a series of feed experiments would be carried out while the boiler parameters were varied over a predetermined range. When the experimental protocol was developed, it was apparent that no operator of a large scale generator would allow such variations since allowing the unit to be used in that manner would require that it be removed from the power grid during the tests. Further, such tests would not necessarily reflect the changes in conditions dictated by changes in demand on the system. In view of these considerations, the following set of experiments was deemed most appropriate:

- a series of experiments would be conducted using the PCB-feed rate as the parameter;
- the boiler under test would be operating in the normal manner with the parameters of its operation monitored;
- sampling of the effluent streams would be such as to provide data over significant operational periods (four hours per sample);
- all effluent streams would be monitored for both emission rate and PCB content.

A comparison of the experiment reported herein with the Protocol for this program (see Volume 2) shows that there were significant deviations from the proposed Protocol. The major differences are detailed in Table 1.

TABLE 1. VARIANCES IN EXPERIMENTAL DESIGN

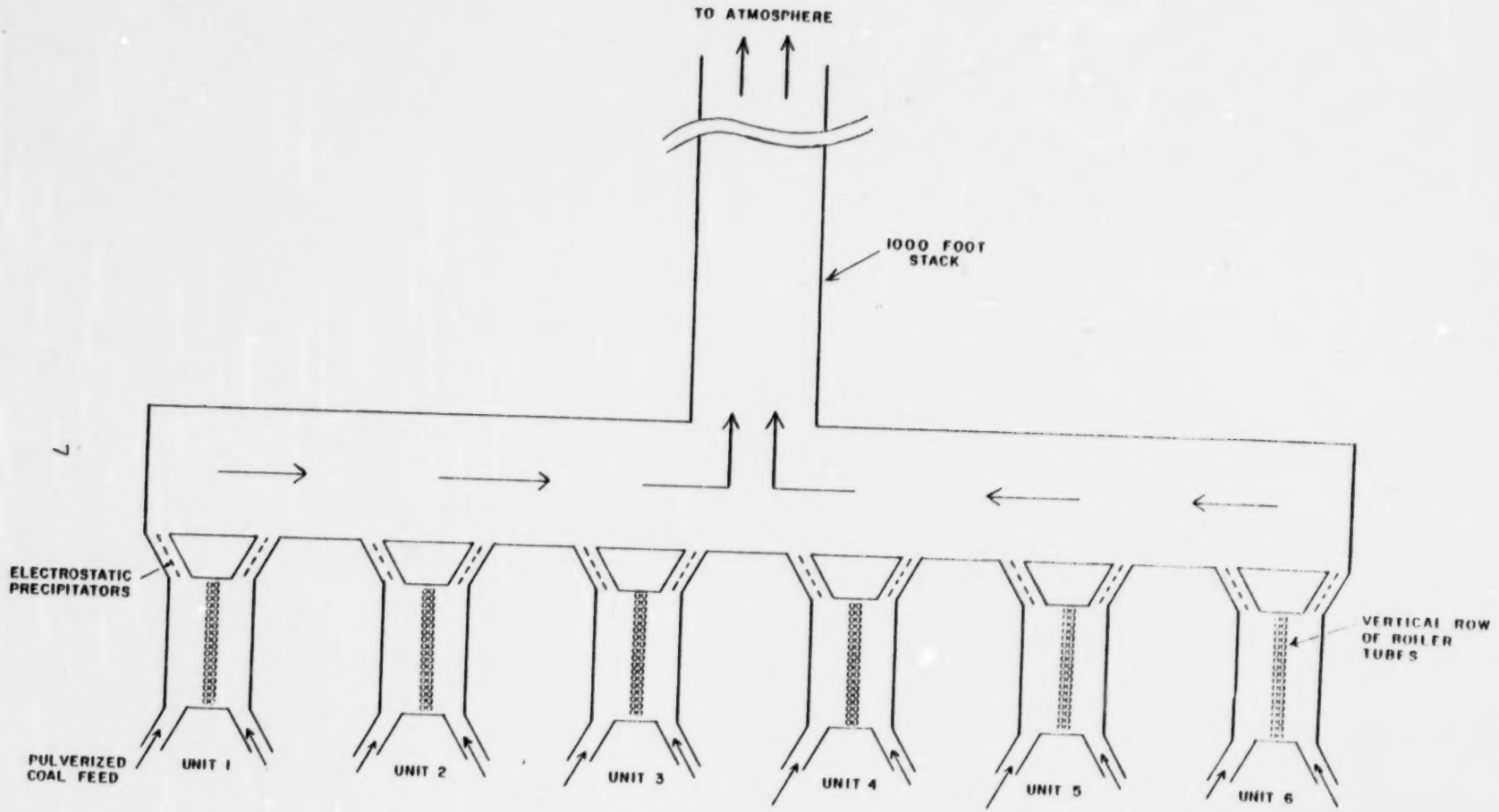
Protocol (Volume 2)	Actual Experiments	Reason for Change
Parametric study using variable coal feed rate, temperature, PCB feed rate, excess O_2	On-line normal operation using PCB feed rate as variable parameter	Real-world conditions required
Feed rate of 20, 60, and 120 gal/hr	Feed at 60 gal/hr per nozzle on alternate sides of boiler and finally on both sides simultaneously	Nozzle designed for 60 gal/hr with feed pressure 140 psi precluded use of 20 gal/hr rate
Fly ash sampled upstream of ESP* using EPA Method V	Fly ash production rate determined using Method V. PCB concentration samples taken from ESP* hoppers	Change occasioned by the finding that the hoppers could be emptied at will thus obviated concern over non-representative samples
Feed at unspecified lance site	Feed on alternate sides and then finally on both sides simultaneously	The division of the fire box into two thermally isolated regions offered additional background data

*ESP = Electrostatic precipitators

WIDOWS CREEK NUMBER ONE BOILER

The Widows Creek Complex of the Tennessee Valley Authority lies in a rural setting on the west side of the Tennessee River approximately 5 km south of the town of Bridgeport, Alabama. The complex consists of six coal-fired boilers served by a single stack (these are the older units) and an additional two larger coal-fired boilers. The six boilers are each fed with pulverized coal and, after passing through the boiler, the combustion gases are passed through cascaded electrostatic precipitators and then into the plenum of the common stack. This arrangement is shown in the schematic Figure 1. All of the six boilers are of approximately the same age and all are essentially identical. Since Boiler Number One was located nearest to an exterior loading dock, it was selected as the logical choice for these tests. The aspects of Boiler Number One that are relevant for the purposes of this discussion are shown in the highly simplified schematic on Figure 2. It is of importance to note, from Figure 2, that the exhausting combustion gases from the boiler are divided within the boiler so as to form two separate streams which will be labeled A and B in what follows. This division is not arbitrary since the fire box is thermally divided into two separate parts by a double set of water tubes that run vertically through the center of the fire box (as illustrated in Figure 2). Each side of the boiler is fitted with eight coal-feed guns through which pulverized coal is driven by the primary combustion air. In addition to these eight coal nozzles, each side of the boiler is also equipped with eight oil lances through which high pressure fuel oil can be injected during the startup from a cold furnace. These lances will be further discussed below.

The general characteristics of Boiler Number One are tabulated in Table 2.



BOILER UNITS ONE THROUGH SIX

FIGURE 1.

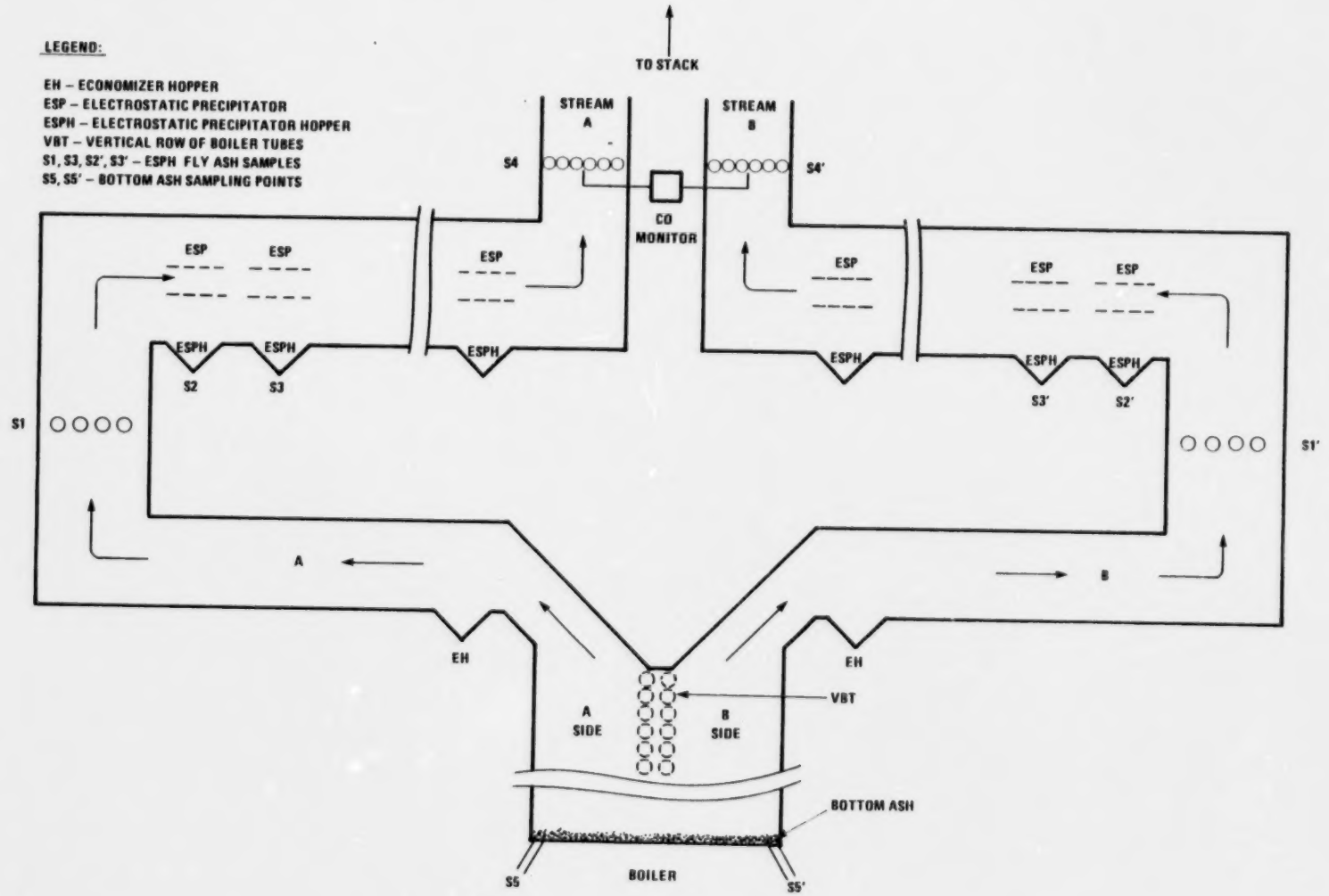


FIGURE 2. SCHEMATIC OF WIDOWS CREEK BOILER NUMBER ONE

TABLE 2. PHYSICAL DATA ON WIDOWS CREEK BOILER NUMBER ONE

Nominal power rating	125 megawatts	
Maximum continuous steam generation	4.54×10^5 kg/hr	(1×10^6 lb/hr)
Water wall area	2.23×10^3 m^2	(24,000 ft^2)
Steam pressure at outlet	1.04×10^6 kg/m^2	(1475 lb/in^2)
Maximum temperature at superheater outlet	539°C	(1003°F)
Boiler width	12.19 M	(40 ft)
Boiler vertical height	30.4 M	(99 ft 9 in.)
Coal feed (nominal)	50.8 tonnes/hr	(56 tons/hr)
APC equipment	cascaded ESPs.	

Although the control of such a boiler requires a large variety of on-line instrumentation, only the following elements of that instrumentation are of interest to what follows:

- coal feed rate
- excess oxygen in combustion gases
- residual CO concentration
- power output from individual boiler/generator
- boiler exhaust gas temperature.

Examples of the use of these data are presented later in Section 4.

PCB FEED SYSTEM

The PCB-contaminated oil was fed through the oil lances on the feed-face of the boiler. The characteristics of these lances was such that, in order to obtain proper atomization, the feed rate was at least 230 l/hr (60 gal/hr) at a nominal pressure of 9.84×10^4 kg/m^2 (140 psi). Because of safety, TVA did not wish to have the oil-carrying tanker within the boiler building. This made it necessary to use a feed line of about 30 meters between the tanker and the actual feed face of the boiler. With safety such an important requirement it was deemed necessary that the feed system shown in the schematic Figure 3 be constructed.

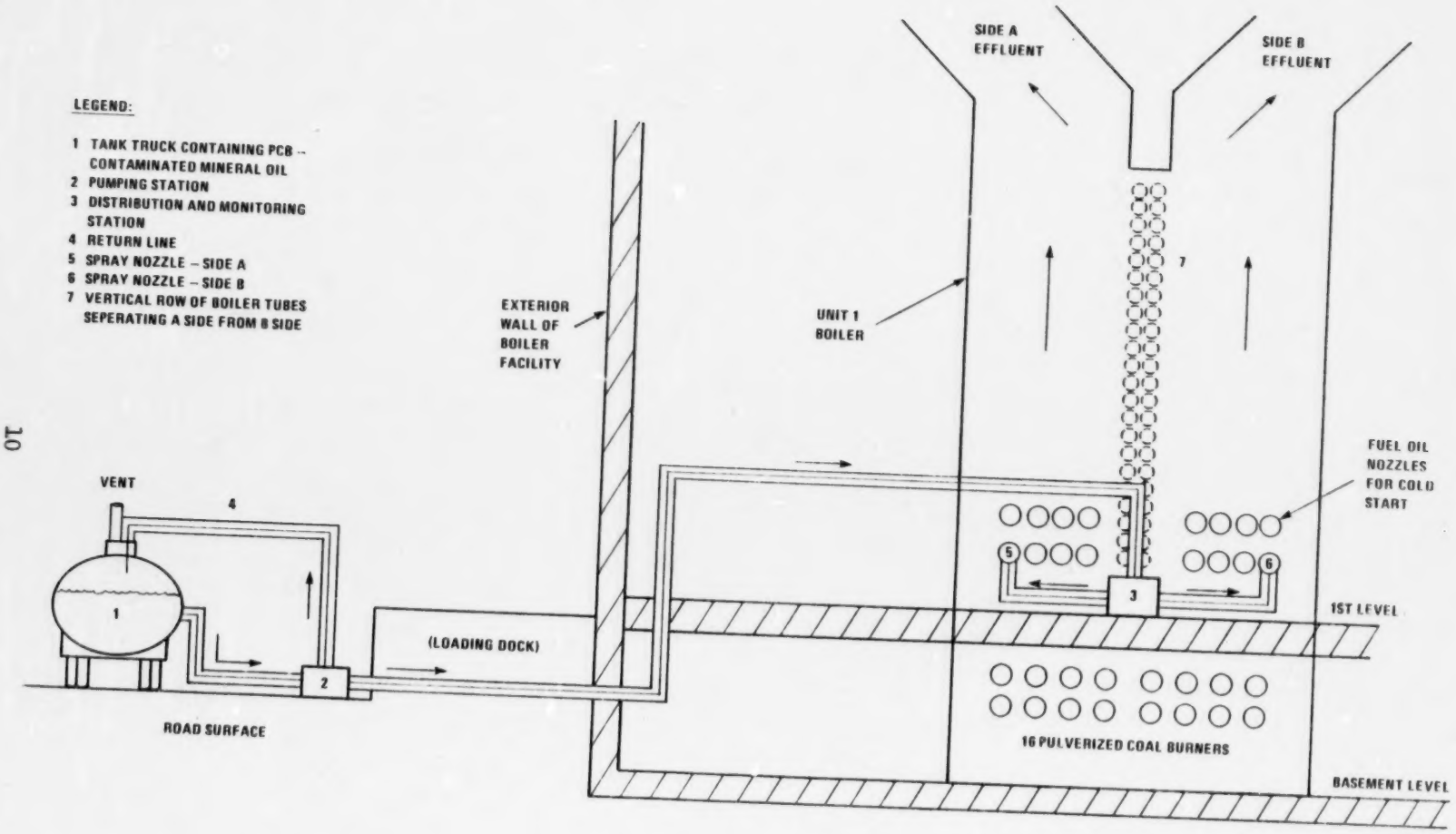

LEGEND:
1 TANK TRUCK CONTAINING PCB – CONTAMINATED MINERAL OIL
2 PUMPING STATION
3 DISTRIBUTION AND MONITORING STATION
4 RETURN LINE
5 SPRAY NOZZLE – SIDE A
6 SPRAY NOZZLE – SIDE B
7 VERTICAL ROW OF BOILER TUBES SEPERATING A SIDE FROM B SIDE
SIDE A EFFLUENT
SIDE B EFFLUENT
EXTERIOR WALL OF BOILER FACILITY
UNIT 1 BOILER
FUEL OIL NOZZLES FOR COLD START
VENT
(LOADING DOCK)
1ST LEVEL
ROAD SURFACE
16 PULVERIZED COAL BURNERS
BASEMENT LEVEL

FIGURE 3. SCHEMATIC OF PCB–CONTAMINATED OIL FEED SYSTEM

Since this system was highly successful and since it appears to have potential application to other hazardous waste transport problems, a detailed discussion of the system is provided as an appendix of the Protocol (Volume 2) . Suffice it to say here that the system consisted of three elements: (a) the pumping station that was located on the loading dock adjacent to the tanker; (b) the metering and control station that was located at the boiler feed face; and (c) the feed line that connected the two units. Both the pumping station and the metering station were enclosed in one-half inch plexiglass and thereby sealed during operations. In addition, the transfer line was one-half inch copper soldered at the junctions and enclosed in a continuous plastic tube that would serve to convey any leak to either of the control stations. The adequacy of the safety precautions is demonstrated by the fact that the PCB levels indicated in the immediate vicinity of either of the control stations were below detection limit (see Appendix A).

PCB-CONTAMINATED OIL

According to the Interagency Agreement between TVA and EPA, the former was to supply the contaminated transformer oil from their supplies at Muscle Shoals, Alabama. When it was determined that the oil in stock was contaminated at a level of the order of 50 ppm, permission was requested of the Regional Administrator of EPA Region IV to add Aroclor 1254 PCBs to increase the concentration up to approximately 450 ppm. Permission was granted, and TVA agreed to supply the additional PCBs.

On arrival of the tanker carrying the contaminated oil, the additional PCBs were added to the oil and mixing was effected by driving the tanker around the area for several hours. The original PCBs in the oil plus the amount of additional PCBs provided (presumably as an Askarel) were only sufficient to produce a feed concentration of (average) 215 ppm. This, however, proved sufficient to allow measurement of DE greater than 99.9% at the analytical detection limits available.

SAMPLING

The Destruction Efficiency, DE, in percent is defined by the relation:

$$DE = \frac{Q - Q_{emitted}}{Q} \times 100$$

where Q is the PCB feed rate and $Q_{emitted}$ is defined by the relation

$$Q_{emitted} = \Sigma_i \Delta_i C_i$$

where Δ_i is the production rate of the i^{th} effluent stream and C_i the PCB concentration of the i^{th} stream. The summation is to be taken over all effluent streams which includes the combustion gases, the fly ash and the bottom ash.

The combustion gases are taken through a series of cascaded ESP prior to release into the atmosphere. There was originally some concern that grab samples taken from the ESP hoppers would not be representative of conditions that existed during the PCB-feed experiments. With this in mind, it was proposed that EPA Method Five be applied upstream of the ESP bank in order to both determine the fly ash production rate and to obtain representative samples of fly ash for PCB determinations. In practice it was found that because the hoppers could be emptied at will, a better approach would be to empty the hoppers at the beginning of the PCB feed and to then sample the first two hoppers in each bank after one hour. Following that initial sample, additional samples were taken at two hour intervals.

It was, of course, necessary that actual Method Five samples be taken from each side of the system in order to determine the fly ash production rate. This was accomplished during the background runs that preceded the PCB injection experiments.

Measurement of the bottom ash production rate proved not to be possible. The physical arrangement of the furnace bottom is such that

bottom ash is ejected at irregular intervals into a wet sluice and thence carried away to a settling pond. In addition, the physical form of the ash was that of a lava-like material which proved to be intractable in the laboratory. The only alternative to a direct measurement of bottom ash production rate was to take the difference between the non-combustible input rate and the fly ash production rate. This process is not so simple as it appears at first glance since the measured fly ash production rate is high and since there is always a residual combustible component in the fly ash. This point will be taken up again when the results of the experiments are discussed.

The stack samples were taken at a horizontal plane in the plenum downstream of the ESPs. Even though this plane was located closer to obstructions at each end (bends) than is normally recommended, the existence of flow correction devices at each end resulted in a relatively uniform, well-defined, smooth flow as is shown in Figures 4 and 5 (courtesy TVA). Figure 4 shows the typical temperature profile within the plenum at the sampling plane, while Figure 5 is a plot of the spatial variation of the square root of the velocity pressure in the same plane. Clearly, the flow correction devices are effective and this plane was appropriate for obtaning representative samples.

The exhaust plenum was fitted with eight (8) sampling ports. The sampling protocol required sampling at six (6) points on each traverse for five (5) minutes at each point. Thus, the sampling time was four (4) hours. In order to make maximum use of the possible background information, sampling was conducted on both the A and B plenums simultaneously.

In past experiments, it has been found that the process of removing the sampling train from the ice bath frequently resulted in sample contamination. In order to avoid this during these experiments the system shown in Figure 6 was constructed. Each sampling train was, after laboratory cleaning and the impinger fluid added, sealed and placed in its own ice bath. The entire assembly was then covered. When it was necessary to use a particular train, the cover was removed, the end seals removed,

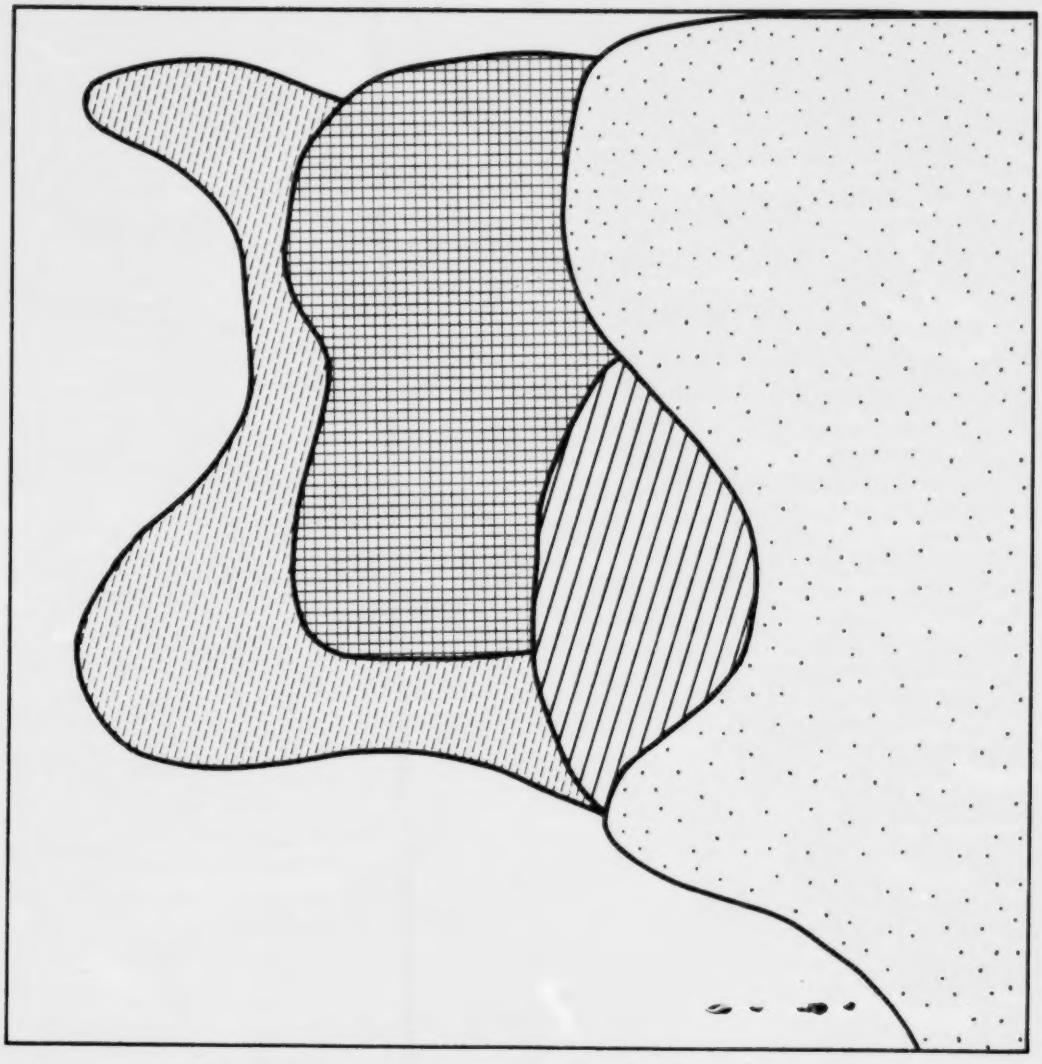
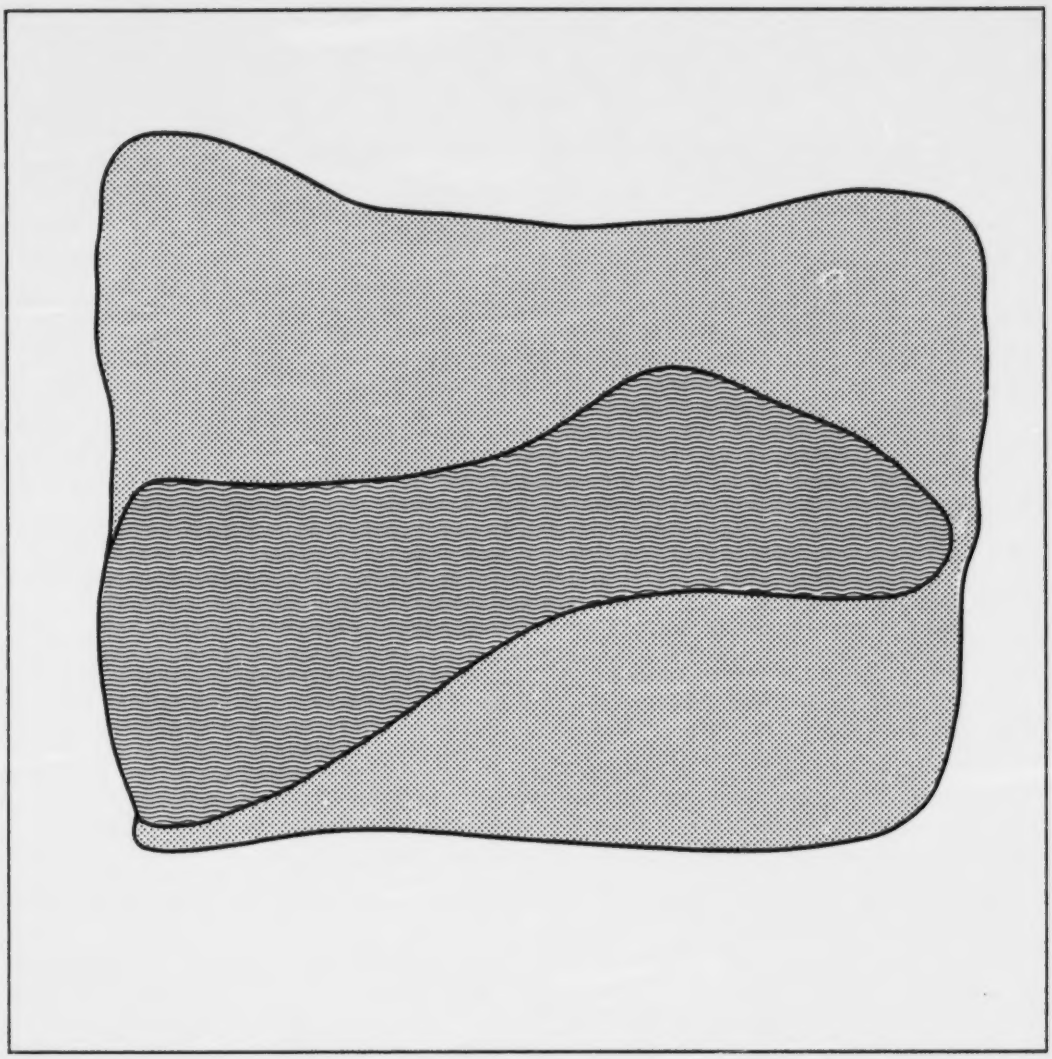


FIGURE 4. MEASURED TEMPERATURE DISTRIBUTION IN DUCT AT POINTS S4 AND S4′ ON FIGURE 2.



LEGEND:

$0.97 \leq \sqrt{h} \leq 1.00$

$0.9 \leq \sqrt{h} \leq 0.97$

$\sqrt{h} < 0.9$

WHERE h IS THE MEASURED VELOCITY PRESSURE AND THE FLOW VELOCITY IS PROPORTIONAL TO $\sqrt{h}$.

FIGURE 5. VELOCITY PROFILE AT POINTS S4 AND S4′ ON FIGURE 2.

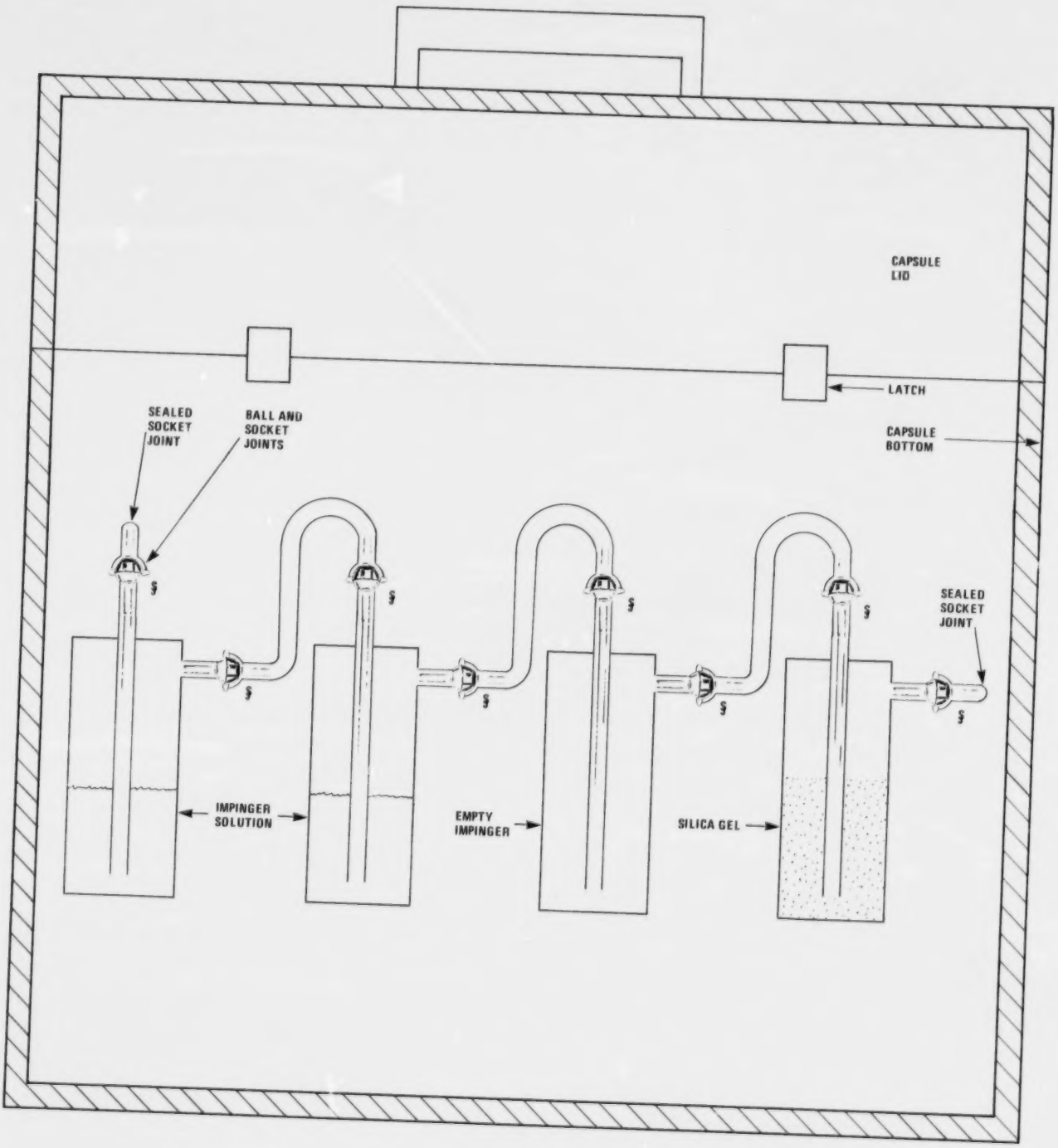


FIGURE 6. ENCAPSULATED PCB SAMPLING TRAIN

and the train connected to the probe and the metering assembly. At the completion of the sampling, the connections were removed, the train resealed and the cover replaced. In this way the only handling of the train components was in the laboratory. As a further check on the procedure, several identical trains were prepared as method blanks. These were treated exactly as were the sample trains except that they were simply exposed and then re-covered.

SECTION 4

EXPERIMENTAL DATA

The data derived from these experiments are presented in the sections that follow. The initial sections present the operational parameters of the boiler during the pretest period and during the PCB feed experiments, and the flue gas data in condensed form. This will be followed by the fly ash data, which are presented along with the TVA data sheet on the general characteristics of the coal feed during the experimental period. Finally, a summary of the PCB concentration data is presented with the detailed laboratory report appended as Appendix B.

BOILER OPERATIONAL DATA

The measured boiler operational data are presented in Figures 7 through 10. An example of the TVA supplied operational data is displayed in Appendix C. Since the injection of PCB-contaminated oil was not begun until 11 November, 1981, the data presented in Figure 7, for 10 November, 1981 represents the normal operating conditions for Boiler Number One. Since the boiler was on-line at this time (and during the entire experimental period) the data in Figure 7 represent the manner in which the boiler parameters vary in response to the load demands that are placed on the boiler.

PCB-contaminated oil was fed to the boiler during the period from 11 November through 13 November. The operational data displayed in Figures 8 through 10 represent the conditions that existed within the boiler during these feed experiments. Here again, the boiler was on line, and therefore the variations in demand are reflected in the variations of the several measured parameters.

Several comments are in order. As is noted in Figures 7 and 8 the CO monitor was not available during these two days. This is somewhat

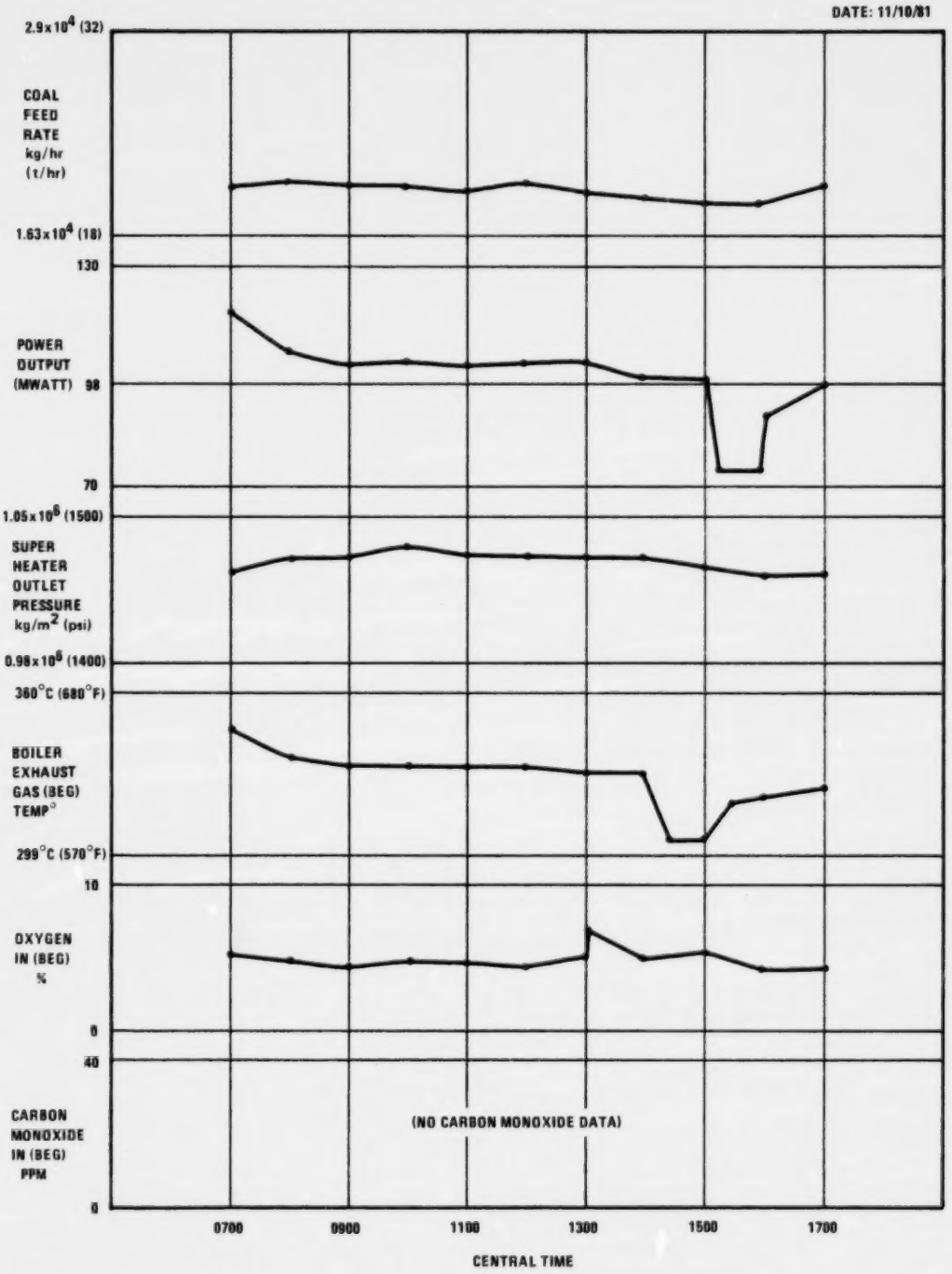


FIGURE 7. UNIT ONE PERFORMANCE DATA DURING BACKGROUND EXPERIMENT

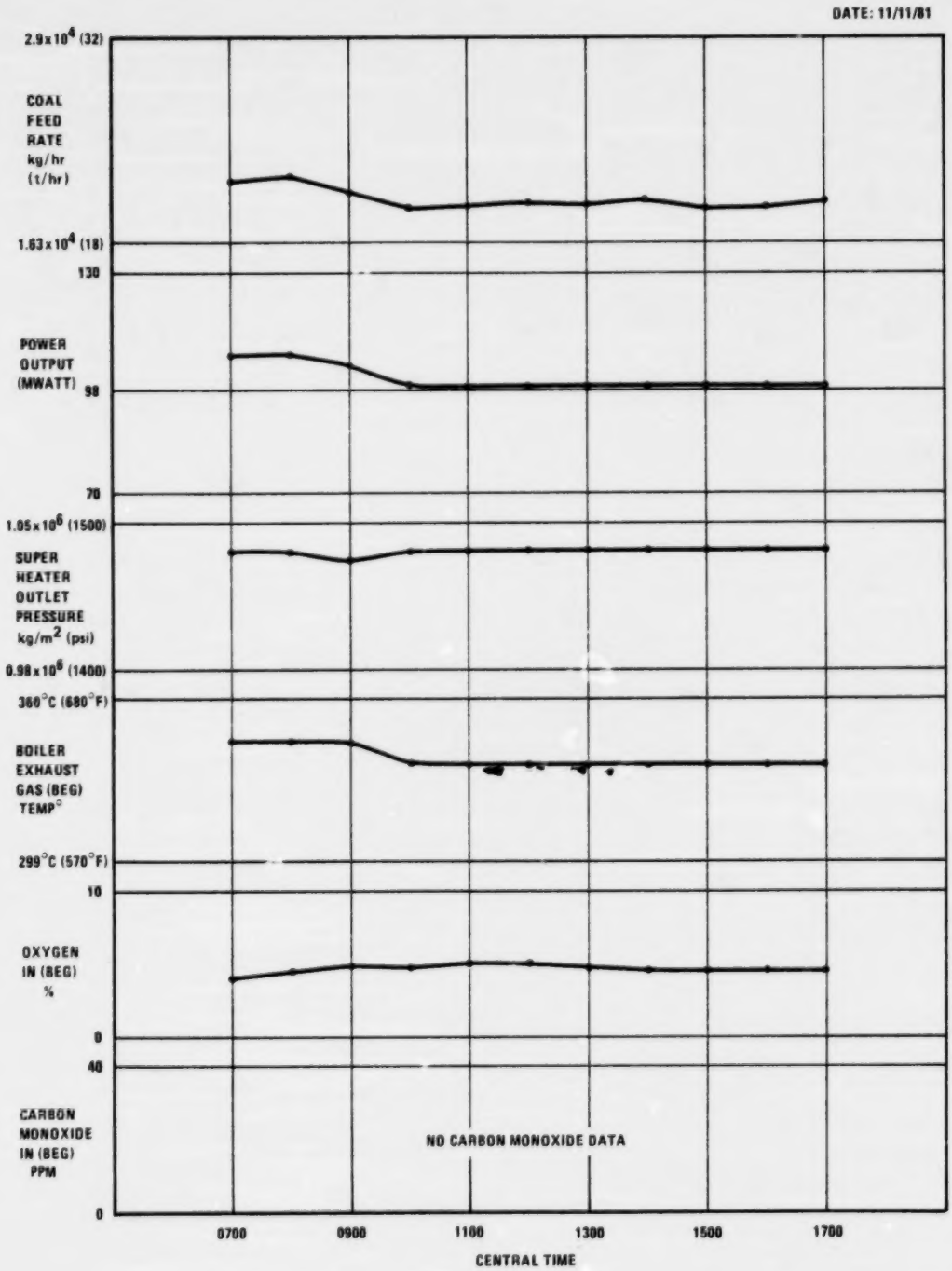


FIGURE 8 UNIT ONE PERFORMANCE DATA DURING EXPERIMENT NO. 1

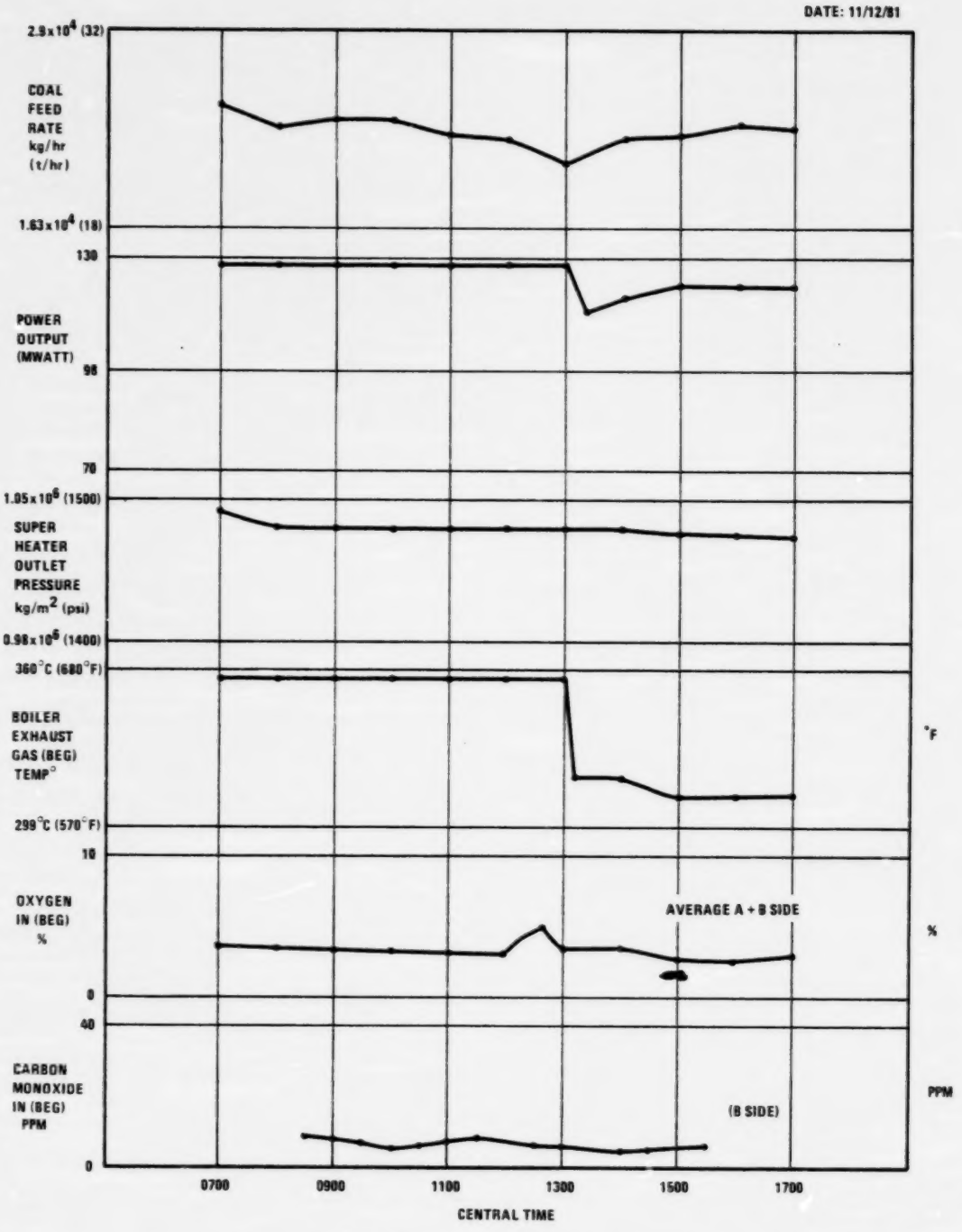


FIGURE 9 UNIT ONE PERFORMANCE DATA DURING EXPERIMENT NO. 2

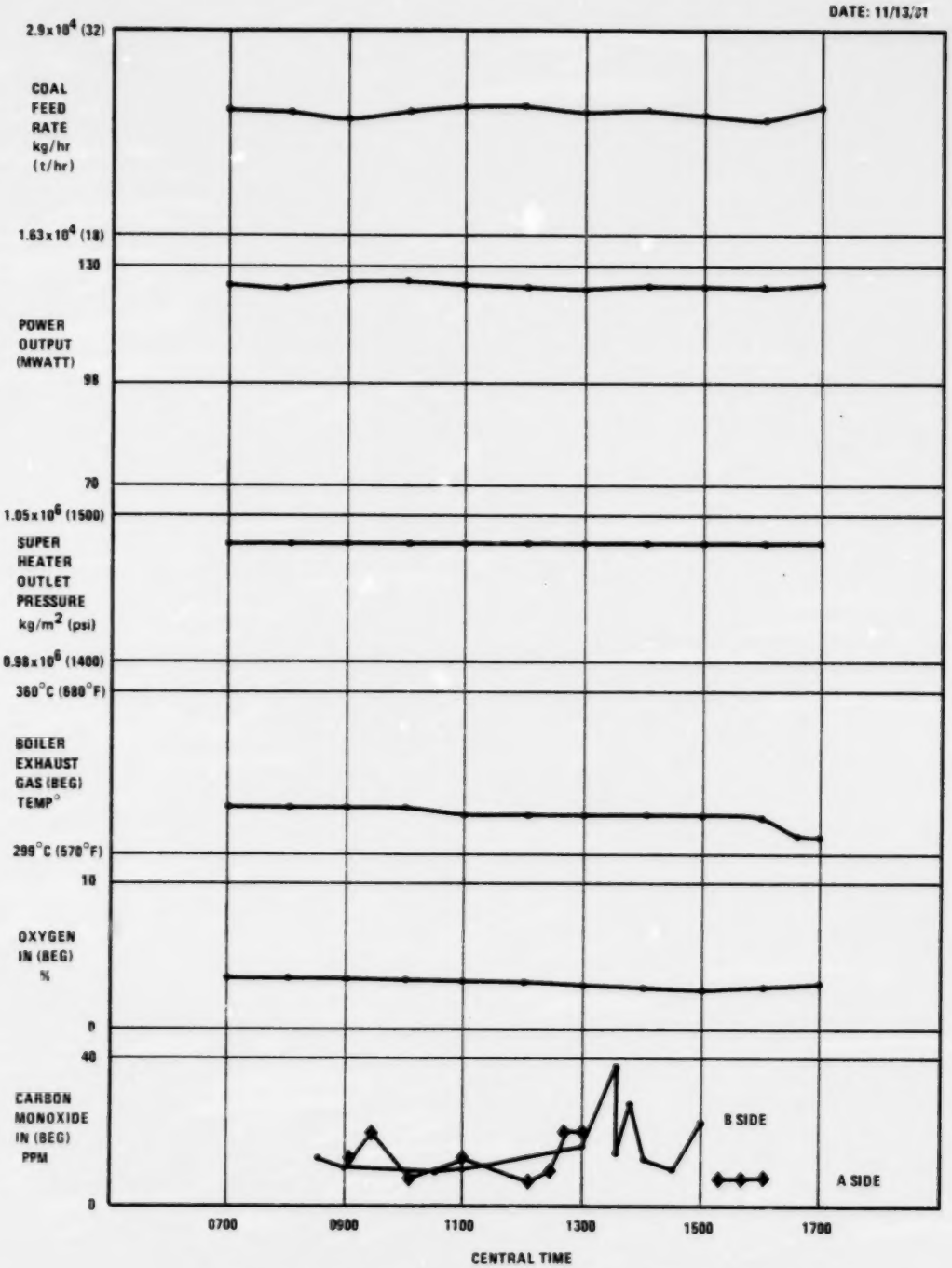


FIGURE 10 UNIT ONE PERFORMANCE DATA DURING EXPERIMENT NO. 3

unfortunate in light of the apparently significant variations in the CO concentrations as observed in Figure 10 (which were taken during the third experiment with equal feed on each side of the boiler). Comparison of the CO concentrations and the variations with time for the second experiment (Figure 9) with those during the third experiment (Figure 10) suggests that there could have been some effect on the CO concentration resulting from the PCB-contaminated oil. Unfortunately, the absence of data during the background run (Figure 7) and the first experiment (Figure 8) makes such a conclusion speculative.

FLUE GAS DATA

The flue gases on each side of the boiler were sampled downstream of the ESP cascade. The results of these sampling efforts are displayed in Table 3 (next page). Each sample represents a total sampling time of the order of four (4) hours. It should be noted that from 11 November through 13 November, simultaneous flue gas samples were taken on the A and B sides at the locations denoted as S4 and S4' in Figure 2.

As has been stated before, the rate of production of fly ash was determined by application of EPA Method Five upstream of the ESP cascade at points denoted as S1 and S1' in Figure 2. The results of those measurements are displayed in Table 4.

TABLE 4. FLY ASH PRODUCTION RATE

Site	Gas Sample Volume (SCF)	Ash Collected (gm)	Ash Concentration (gm/SCF)
S1	66.23	10.17	0.154
S1'	52.86	8.041	0.152

TABLE 3. SUMMARY OF STACK SAMPLING DATA

Date	PCB Feed Status	Sampling Location	Sample Volume		Throughput in Duct	
			SCM	(SCF)	SCMM	(SCFM)
11/9/81	No feed	Upstream ESP-A	1.876	(66.23)	5136	(1.81×10^5)
11/10/81	No feed	Upstream ESP-B	1.497	(52.86)	4106	(1.45×10^5)
11/11/81	PCB Feed A	Downstream ESP-A	2.941	(103.86)	5013	(1.77×10^5)
11/11/81	PCB Feed A	Downstream ESP-B	2.562	(90.46)	4050	(1.43×10^5)
11/11/81	PCB Feed A	Downstream ESP-A	3.067	(108.29)	4814	(1.70×10^5)
11/12/81	PCB Feed B	Downstream ESP-B	1.865	(65.86)	3710	(1.31×10^5)
11/12/81	PCB Feed B	Downstream ESP-A	2.806	(99.08)	4390	(1.55×10^5)
11/12/81	PCB Feed B	Downstream ESP-B	3.168	(111.85)	4984	(1.76×10^5)
11/12/81	PCB Feed B	Downstream ESP-A	2.565	(90.56)	4305	(1.52×10^5)
11/13/81	PCB Feed A&B	Downstream ESP-B	2.961	(104.54)	4956	(1.75×10^5)
11/13/81	PCB Feed A&B	Downstream ESP-A	2.892	(102.13)	5098	(1.80×10^5)
11/13/81	PCB Feed A&B	Downstream ESP-B	2.835	(100.09)	4758	(1.68×10^5)
11/13/81	PCB Feed A&B	Downstream ESP-A	2.971	(104.91)	5126	(1.81×10^5)
11/13/81	PCB Feed A&B	Downstream ESP-B	3.038	(107.27)	4871	(1.72×10^5)

PCB CONCENTRATIONS

Since the analytical results are of considerable significance a detailed report on the analytical processes and results is presented as Appendix B. All results indicate that the PCB concentrations in samples taken from the system were below detection levels. The gas stream chromatograms were uniformly clear of any indication of residual PCBs. On the other hand, careful analysis of the flyash chromatograms indicates that PCBs may have been present but at concentration levels well below those that could be reliably quantified. The possible consequences of these apparent residual levels of PCBs is discussed in Section 5.

SECTION 5

CALCULATIONS AND RESULTS

In the sections that follow are discussed the effect of PCB-contaminated oil feed on the boiler efficiency, fly ash loading and its relationship to the total non-combustibles in the coal, the destruction efficiency, and finally the sensitivity of the calculated destruction efficiency to errors in such parameters as rates of production of the various effluent streams.

EFFECT OF PCB FEED ON BOILER EFFICIENCY

To estimate the effect of the PCB-contaminated oil feed on the boiler efficiency we may compare the efficiency as observed during the background run with that observed during Experiment 3 during which the PCB feed was at its maximum. For this exercise we will utilize a simplistic measure of efficiency defined as:

$$\text{Boiler Efficiency} = \frac{\text{Power Output}}{\text{Total Heat Input}}$$

where the total heat input is computed by considering the heating value of the coal to have an average value of 6.11×10^3 kcal/kg (11000 BTU/lb). The results of such calculations for the background run are tabulated in Table 5 while those for the third experiment are tabulated in Table 6.

TABLE 5. BOILER EFFICIENCY IN ABSENCE OF PCB FEED*

Time	Coal Feed (kg/hr)	Heat Input** (kw $\times 10^{-8}$)	Output (MW)	Efficiency (%)
0700	19704	1.40	118	84.29
0900	19704	1.40	102	72.86
1100	19250	1.366	102	74.67
1300	19068	1.354	105	77.55
1500	18796	1.334	98	73.46
1700	19704	1.398	96	68.67
			Average	75.25
			Std. Deviation	4.823

*Data from Figure 7.
**Heating value of fuel from operating data as in Appendix C.

TABLE 6. BOILER EFFICIENCY IN PRESENCE OF PCB FEED*

Time	Coal Feed (kg/hr)	Coal Feed (kw x 10^{-8})**	Output (MW)	Efficiency (%)
0700	24062	1.709	124	72.55
0900	23336	1.656	126	76.08
1100	24334	1.729	125	72.30
1300	23699	1.682	124	73.72
1500	23608	1.677	124	73.94
1700	24334	1.729	125	72.30
			Average	73.48
			Std. Deviation	1.334

*Data from Figure 10.
**Heating value coal from operating data as in Appendix C.

Even though the average values of overall boiler efficiency as computed in Tables 5 and 6 suggests that there was a decrease of approximately 1.77% in the average efficiency in the presence of PCB feed, the large standard deviation shown in Table 5 indicates that, with high probability, these results are not different. Hence, one can say with some assurance that, PCB-contaminated oil had no significant effect on the boiler efficiency. Deletion of the initial (at 0700) high value of 84.29% from Table 5 would result in an average efficiency of 73.44%, as compared to 73.48% with PCBs present (Table 6).

FLY ASH/BOTTOM ASH PRODUCTION RATES

The detailed boiler operations data sheet for the period November 8-15, 1981 is appended as Appendix C. We note several specific data from that data sheet which are displayed in Table 7.

TABLE 7. BOILER PARAMETERS (8-15 November, 1981)

Total non-combustibles in coal	14.2%
Residual combustibles in fly ash	13.9%

The fly ash concentrations as reported in Table 4 were determined on 9 and 10 November, 1981, during which the flue gas production rate was determined to be 9232 SCMM (3.26×10^5 SCFM) (Table 3). Using the average fly ash concentration of 5.40 g/SCM (0.153 g/SCF), the fly ash production rate, Q_f, is found to be

$$Q_f = 5.40 \times 9232 \times 60 = 2.99 \times 10^3 \text{ kg/hr.}$$

During this same interval the average fuel feed was 2.087×10^4 kg/hr (4.6×10^4 lb/hr) (from Figures 7 and 8) which had an average non-combustible content of 14.2% (Table 7). Hence, the rate of injection of non-combustibles into the boiler, Q_n, was

$$Q_n = 0.142 \times 2.087 \times 10^4 = 2.964 \times 10^3 \text{ kg/hr.}$$

Further, we note from Table 7 that the combustible residue in the fly ash was 13.9%, hence the non-combustible contribution to the fly ash, Q_{fn}, was found to be

$$Q_{fn} = \frac{2.964 \times 10^3}{1.139} = 2.602 \times 10^3 \text{ kg/hr.}$$

Consequently, the bottom ash production rate, Q_b, was found to be

$$Q_b = Q_n - Q_{fn} = 0.362 \times 10^3 \text{ kg/hr.}$$

In this case the 'usual' division between fly ash and bottom ash of 80% to 20% appears to be violated. The measured ratio is 88%/12%.

DESTRUCTION EFFICIENCY (DE)

The destruction efficiency, DE, is defined as

$$DE = \frac{Q - Q_{emitted}}{Q} \times 100\%$$

where Q is the PCB feed rate and

$$Q_{emitted} = \Sigma_j \Delta_j C_j$$

where Δ_j is the production rate of the j^{th} effluent stream with concentration (of PCBs) C_j. The effluent streams of interest are the fly ash and the flue gases.

From the average of the measured PCB concentrations of the oil of 215 ppm (from Table 7 - Appendix B) and the oil density of 85.6 g/l (from Table 8 - Appendix B) the relevant PCB feed rates are as shown in Table 8.

TABLE 8. PCB FEED RATE (Q)

Experiment	Oil Feed Rate		Feed Side	PCB Feed Rate (Q)	
	l/hr	(gal/hr)		gm/hr	(lb/hr)
1	227	(60)	A	41.77	(0.092)
2	227	(60)	B	41.77	(0.092)
3	454	(120)	A&B	83.54	(0.184)

To now compute the PCB emission rates we first note that no PCBs were detected in the samples (except for the probe washings from box 5 which was apparently due to contamination) but also that many of the fly ash sample chromatograms show residuals that strongly resemble Aroclor 1254 but at concentrations below the detection limit. In view of this finding, it must be assumed that the residual PCB concentration on the fly ash is below the detection level but probably not zero. We also note, in this context, that the fly ash samples taken on the control side (for example B side in Experiment 1) strongly resemble those from the feed side. This suggests that a calculation based on the assumption that the observed chromatographic peaks on the feed side are due to residual PCBs is quite likely to overstate the case and result in a calculated DE that is less than that actually obtained.

To now compute the PCB emission rate associated with the fly ash we must first compute the total fly ash emission rate for each of the experiments and then calculate the partitioning between the two sides. We use the relationship between fly ash production shown in Table 4 and the actual coal feed rates taken from Figures 8 through 10. The results are presented in Table 9.

TABLE 9. ESTIMATED TOTAL FLY ASH PRODUCTION RATE*

Experiment	PCB Feed Side	Coal Feed Rate		Fly Ash Production (Total)	
		kg/hr	(lb/hr)	kg/hr	(lb/hr)
		$\times 10^{-4}$		$\times 10^{-3}$	
1 AM	A	1.966	(4.33)	2.815	(6.20)
1 PM	A	1.870	(4.12)	2.679	(5.90)
2 AM	B	2.315	(5.1)	3.319	(7.31)
2 PM	B	2.188	(4.82)	3.137	(6.91)
3 AM	A&B	2.397	(5.28)	3.437	(7.57)
3 PM	A&B	2.384	(5.25)	3.414	(7.52)

*Based on 14.33% ash content of coal from Appendix C.

It is now appropriate to compute the ash load of the A and B ducts during these experiments. We will assume equal concentrations in the two ducts so that the hourly load will depend on the relative gas flow volumes in the two ducts. The latter data are taken from Table 3. The results of these calculations are displayed in Table 10.

TABLE 10. ESTIMATED FLY ASH PRODUCTION RATE - A AND B STREAMS

Experiment*	PCB Feed Side	A Duct		B Duct	
		kg/hr	(lb/hr)	kg/hr	(lb/hr)
		$x10^{-3}$		$x10^{-3}$	
1 AM	A	1.59	(3.51)	1.22	(2.69)
1 PM	A	1.51	(3.33)	1.17	(2.57)
2 AM	B	1.55	(3.42)	1.77	(3.89)
2 PM	B	1.46	(3.21)	1.68	(3.69)
3 AM	A&B	1.78	(3.92)	1.66	(3.65)
3 PM	A&B	1.75	(3.85)	1.66	(3.66)

*Each experiment lasted 8 hrs, 4 hrs in the morning (AM) and 4 hrs in the afternoon (PM).

In order to make the most conservative estimate of the DE from these experiments, we will assume that the PCB concentration of both the flue gases and the fly ash lies just at the detection limit for each matrix. The detection limit for the fly ash is taken as 2 ng/g (Appendix B) so that the maximum emission rate associated with the fly ash is as displayed in Table 11.

TABLE 11. MAXIMUM PCB EMISSION RATE ASSOCIATED WITH FLY ASH

EXPERIMENT	A Duct (gm/hr x 10^3)	B Duct (gm/hr x 10^3)
1 AM	3.18	2.44
1 PM	3.02	2.34
2 AM	3.10	3.54
2 PM	2.92	3.36
3 AM	3.56	3.32
3 PM	3.50	3.32

Again, taking the detection limit for the flue gas samples as 0.2 x 10^{-6} gm per RAC sample (Appendix B), and the flue gas production rates from Table 3, the maximum PCB emissions associated with the flue gases are tabulated in Table 12.

TABLE 12. MAXIMUM PCB EMISSIONS IN EFFLUENT GASES

EXPERIMENT	A Duct (gm/hr x 10^2)	B Duct (gm/hr x 10^2)
1 AM	2.045	1.900
1 PM	1.880	2.388
2 AM	1.875	1.889
2 PM	2.016	2.007
3 AM	2.116	2.016
3 PM	2.070	1.925

We now combine the possible emission from both flue gas and fly ash and compute the resulting estimate of the minimum DE as shown in Table 13.

TABLE 13. MINIMUM DE CONSIDERING FLUE GASES AND FLY ASH

EXPERIMENT	FEED SIDE	MINIMUM DE (%)
1 AM	A	99.89
1 PM	A	99.88
2 AM	B	99.89
2 PM	B	99.89
3 AM	A&B	99.94
3 PM	A&B	99.94

Close examination of the chromatograms that are associated with the flue gas samples indicates that taking the residual concentration of the samples to be at the detection limit is very conservative. One could, with some justification, consider these chromatograms to represent essentially zero PCB concentration. In this case, the resulting emissions would only be associated with the fly ash. The resulting DE calculated on this basis is shown in Table 14.

TABLE 14. VALUES OF DE CONSIDERING ONLY FLY ASH*

EXPERIMENT	FEED SIDE	MINIMUM DE (%)
1 AM	A	99.987
1 PM	A	99.987
2 AM	B	99.984
2 PM	B	99.985
3 AM	A&B	99.992
3 PM	A&B	99.992

*PCB content of flue gases taken to be negligible in comparison to PCB content of fly ash.

SENSITIVITY ANALYSIS

In order to determine the statistical significance of the results that are reported in Tables 12 and 13, it is appropriate to determine the possible effect of errors in the estimates of either the fly ash production rate or the flue gas production rate. Let the possible error in either rate to be designated as δ_j, j=1 represents the fly ash, j=2 represents the flue gases. Then, in terms of the Δ_i,

$$DE' = \frac{Q - \Sigma\Delta_i(1 \pm \delta_i)C_i}{Q} = DE_o \pm (1/Q)\Sigma\delta_i\Delta_i C_i$$

where DE_o is the DE in the absence of error in rate measurements. To illustrate the sensitivity of the DE' to possible errors in either of the rates, we take the partial derivative of the expression for DE' with respect to both δ_1 and δ_2. The resulting expressions are

$$\frac{\delta}{\partial\delta_1}(DE') = (1/Q)\Delta_1 C_1; \quad \frac{\partial}{\partial\delta_2}(DE') = (1/Q)\Delta_2 C_2$$

Since $\Delta_1 C_1 >> \Delta_2 C_2$, the DE' is far more sensitive to δ_2 than to δ_1. To cause a change in the actual DE' from the calculated DE_o from 99.9 to an unacceptable 99.8 would require a significant error in the velocity measurements. To illustrate this, we consider data from Experiment 1 AM during which the PCB feed was on the A side.

The maximum PCB concentration that is consistent with the detection limit is

$$C_{max} = \frac{0.2 \times 10^{-6}}{2.941} = 6.8 \times 10^{-8} \frac{gm}{SCM}$$

(data taken from Table 3 for this calculation). Further, from Table 3 we find that $\Delta_2 = 3 \times 10^5$ SCMH. Hence, for a change in DE (ΔDE) from 99.9% to 99.8%, the required error in Δ_2 is

$$\Delta DE = .001 = 4.89 \times 10^{-4} \delta_2$$

$$\text{or } \delta_2 = 204\%.$$

PCBS IN BOTTOM ASH

It will be noted that in the calculation of DE, the possible contribution due to PCB emissions in the bottom ash has been ignored. If one were to take the residual PCBs in the fly ash to be at the same detection limit as was the case for fly ash, we may combine the data from Section 5 with Experiment 1 AM from Table 11 to compute the maximum PCB emissions associated with the solid waste stream. The resulting minimum DE would then be 99.948% rather than the 99.95 reported in Table 13. This contribution was not included since the physical form of the bottom ash, that similar to lava, indicated that it had been exposed to temperature in excess of the boiling point of PCBs - hence there would be no discernable residue of PCBs.

SECTION 6

BIBLIOGRAPHY

1. U.S. Environmental Protection Agency. PCBs; Disposal and Marking. FR 43:7150, Friday, Feb. 17, 1978.

2. Fisher, A., A. Garwick, T. Hockman, W. Kilgore, D. Koenig; Evaluation of PCB Destruction Efficiency in an Industrial Boiler. EPA Contract No. 68-02-3168, Program Element No. C1Y1B. November, 1980.

3. Sarro, T.L., D. R. Moore, D.G. Ackerman: Emissions Testing During Incineration of PCBs at Rollins Environmental Services, Inc.; EPA Contract No. 68-02-3174. Work Assignment 56. EPA Program Element No. C1L1B; February, 1981.

APPENDIX A
AIR SAMPLING DATA

W. F. Neperud, Superintendent, Widows Creek Steam Plants /a RMS

Robert S. Rainey, Chief, Safety and Industrial Hygiene Branch, 146 FIPB-M

DEC 01 1981

POLYCHLORINATED BIPHENYL SAMPLING - WIDOWS CREEK STEAM PLANTS

On November 12, 1981, members of the Industrial Hygiene Engineering Section collected area samples for airborne polychlorinated biphenyls (PCBs) near the tank trailer, pump, and the injector point at the Unit No. 1 boiler during the EPA/TVA PCB incineration experiment. The sampling data, presented in attachment I, does not indicate any health hazard from airborne PCB exposure.

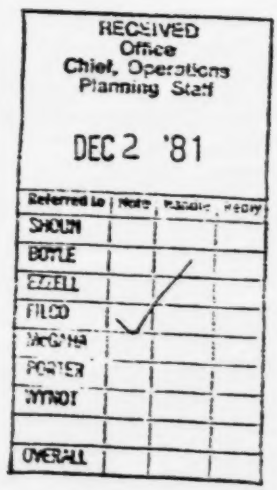
We appreciate the cooperation extended by you and your staff during the survey. If you have any questions concerning this report, please call Bob Weeks in the Chattanooga office at extension 3789.

Robert S. Rainey

JPW:RFW:PKM:JHB
Attachment
cc (Attachment):
B. D. Aldridge, 911 EB-C
W. W. Pilgo, 230 CST2-C

WWF:VTH 12-4-81
xc: Ed Kopetz, 900 CST2-C
Doug Neeley, 124 LSB-K
Ed Patrick, E10B38 C-K
Gil Stauffer, 122 OSWHA-M
John Wallace, 850 CST2-C
Tommy Waters, 419 EB-C

WWF:VTH 1-19-82
xc: Glenn Kuntz, EPA
David Sanchez, EPA
Frank Whitmore, Versar



ATTACHMENT I

SAMPLING DATA FOR THE PCB INCINERATION EXPERIMENT

WIDOWS CREEK STEAM PLANT

NOVEMBER 12, 1981

Location	Sampling Time (Min)	Airborne Concentration (mg/m^3)*
Near tank trailer containing mineral oil contaminated with PCBs, outside of the building	317	<0.01
Near mineral oil pump, outside of the building	314	<0.01
Near the injector point for the mineral oil contaminated with PCBs at the Unit No. 1 boiler	310	<0.01

*Time-weighted average 8-hour occupational exposure limit is 1 mg/m^3 for PCBs containing 42 percent chlorine and 0.5 mg/m^3 for PCBs containing 54 percent chlorine.

APPENDIX B

FINAL ANALYTICAL REPORT
ANALYSIS OF TVA INCINERATOR FEED AND EFFLUENTS

1.0 INTRODUCTION

This report summarizes the results of the analysis of samples from the TVA incinerator for PCB-1254 and provides support in accordance with the document, A Study of PCB Destruction Efficiency and Performance for a Coal-Fired Utility Boiler. Samples were received at Versar and logged into custody on December 2, 1981. A list of samples received is presented in Table 1. The samples were unboxed in the staging laboratory and stored at room temperature on the lab table until March 1, 1982 when analysis began. Because of the great stability of PCBs and the high temperature source of these samples, the risk of sample loss at room temperature was negated.

Analysis was performed according to the Proposed Analytical Scheme dated December 21, 1981, and revised January 8, 1982. Samples were extracted and combined in order to improve detection limits for the analysis. A list of actual samples analyzed is presented in Table 2.

In summary of the results, PCB-1254 was found in the oil feed samples at 210-220 ppm and near the detection limit in one probe washing. The detection limits for each matrix are listed in Table 3.

TABLE B-1

SAMPLES RECEIVED ON DECEMBER 2, 1981 FOR TVA PROJECT 583.2

Matrix	Lab No.	Sample No.	Identification
Oil	7619	Oil-201	Exp#1 Feed oil
	7620	Oil-202	Exp#2 Feed oil; same reservoir as 201
	7621	Oil-203	Exp#3 Feed oil; different reservoir
Coal	7622	Coal-301	Background Coal; do not analyze
	7623	Coal-302	Exp#1 Boiler Feed; do not analyze
	7624	Coal-303	Exp#2 Boiler Feed; do not analyze
	7625	Coal-304	Exp#3 Boiler Feed; do not analyze
RAC Samples	7583	Box #1	Background - duct A up
	7584	Box #2	Background - duct B up
	7585	Box #3	Exp#1 AM; duct A down
	7586	Box #5	Exp#1 AM; duct B down
	7587	Box #6	Control #1 AM (11/11/81)
	7588	Box #7	Exp#1 PM; duct A down
	7589	Box #8	Exp#1 PM; duct B down
	7590	Box #10	Exp#2 AM; duct B down
	7591	Box #11	Exp#2 AM; duct A down
	7592	Box #12	Exp#2 PM; duct A down
	7593	Box #13	Exp#2 PM; duct B down
	7594	Box #14	Exp#3 AM; duct A down
	7595	Box #15	Exp#3 AM; duct B down
	7596	Box #16	Control #2 AM (11/13/81)
	7597	Box #17	Exp#3 PM; duct A down
	7598	Box #18	Exp#3 PM; duct B down
	7599	Box #25	Glassware Blank
Probe Washings	7600	Box #27	11/11/81
	7601	Box #28	11/12/81
	7602	Box #29	11/13/81
Teflon Tubing	7603	1AM-A	Connected probe in stack to impinger train
	7604	1AM-B	
	7605	1PM-A	
	7606	1PM-B	
	7607	2AM-A	
	7608	2AM-B	
	7609	2PM-A	
	7610	2PM-B	
	7611	3AM-A	
	7612	3AM-B	
	7613	3PM-A	
	7614	3PM-B	
	7615	Background A	
	7616	Background B	

TABLE B-1 (Continued)

SAMPLES RECEIVED ON DECEMBER 2, 1981 FOR TVA PROJECT 583.2

Ash	7617	F-101	Background duct A - preburn
	7618	F-102	Background duct B - preburn
Flyash	7626	FA-111	Exp#1; duct A; Hopper 1
	7627	FA-112	Exp#1; duct A; Hopper 2
	7628	FA-113	Exp#1; duct A; Hopper 3
	7629	FA-114	Exp#1; duct A; Hopper 4
	7630	FA-121	Exp#1; duct B; Hopper 1
	7631	FA-122	Exp#1; duct B; Hopper 2
	7632	FA-123	Exp#1; duct B; Hopper 3
	7633	FA-124	Exp#1; duct B; Hopper 4
	7635	FA-211	Exp#2; duct A; Hopper 1
	7636	FA-212	Exp#2; duct A; Hopper 2
	7637	FA-213	Exp#2; duct A; Hopper 3
	7638	FA-214	Exp#2; duct A; Hopper 4
	7639	FA-221	Exp#2; duct B; Hopper 1
	7640	FA-222	Exp#2; duct B; Hopper 2
	7641	FA-223	Exp#2; duct B; Hopper 3
	7642	FA-224	Exp#2; duct B; Hopper 4
	7644	FA-311	Exp#3; duct A; Hopper 1
	7645	FA-312	Exp#3; duct A; Hopper 2
	7646	FA-313	Exp#3; duct A; Hopper 3
	7647	FA-314	Exp#3; duct A; Hopper 4
	7648	FA-315	Exp#3; duct A; Hopper 5
	7649	FA-321	Exp#3; duct B; Hopper 1
	7650	FA-322	Exp#3; duct B; Hopper 2
	7651	FA-323	Exp#3; duct B; Hopper 3
	7652	FA-324	Exp#3; duct B; Hopper 4
	7653	FA-325	Exp#3; duct B; Hopper 5
Bottom Ash	7634	BA-111	Exp#1; duct A - do not analyze
	7643	BA-221	Exp#2; duct B
	7654	BA-311	Exp#3; duct A
	7655	BA-312	Exp#3; duct A
	7656	BA-321	Exp#3; duct B

TABLE B-2

ACTUAL SAMPLES ANALYZED

Matrix	Samples No.
Oil	201, 202, 203
RAC Samples	Box #1, 2, 3, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 25
Filters	Boxes #1, 2 (weight only)
Probe Washings	Boxes #27, 28, 29
Teflon Tubing	3PM-A (from Box #17)
Ash	F-101, 102 (weight only)
Flyash	Composites of FA-111-114, 121-124, 211-214, 221-224, 311-314, 321-324, 315, 325

TABLE B-3

DETECTION LIMITS PER MATRIX

Matrix	Detection Limit
Oil	1 ppm (1 ug/g)
RAC Samples	0.2 ug/RAC Sample (impinger solution plus Florisil plus train washing)
Probe Washings	0.2 ug/Probe Washing
Teflon	0.2 ug/Teflon Tube
Flyash	2 ppb (2 ng/g)

2.0 SAMPLE PREPARATION

2.1 Materials

Rigorous cleaning and sample preparation procedures were followed to avoid contaminating samples with interfering organics including PCBs during sampling and analysis. The effectiveness of cleaning procedures was verified by analytical quality control which demonstrated that interferences were removed.

2.1.1 Solvents

All solvents used were pesticide-grade distilled in glass. Prior to use analysis of each lot was performed by GC/ECD after concentration to demonstrate the required solvent purity.

2.1.2 Florisil

Prior to use, the 30/60 mesh PR-grade Florisil was baked in a muffle furnace at 450°C to remove trace organic contaminants. Following mixing, a 50 gram aliquot of each lot was soxhlet extracted for three hours with 300 ml hexane. The hexane was then concentrated to 1 ml and analyzed by GC/ECD to verify that interferences were removed.

2.1.3 Sodium Sulfate

Sodium sulfate, granular anhydrous, was baked at 450°C in a muffle furnace to remove organics.

2.1.4 Glassware

Glassware washing procedures used were those recommended in the Federal Register, Method 608, December 3, 1979, Page 65901. All glassware was rinsed with the final solvent used prior to delivery to the glassware washing facility. The glassware was washed with hot water and soap and scrubbed with a brush until clean. It was then rinsed with warm tap water followed by deionized water, reagent-grade acetone, and pesticide-grade hexane. The glassware was then air dried and baked in a muffle furnace at 450°C to remove all traces of organics.

2.2 Sample Extraction Procedures

2.2.1 Oil Samples

The three oil samples were analyzed according to procedures routinely used by Versar Inc. The samples were diluted one gram oil in 10 ml petroleum ether. The diluted oils were placed on a column contining 20 g Florisil and were eluted with 200 ml petroleum ether. The eluate was concentrated to 10 ml in Kuderna-Danish apparatus and analyzed by packed column GC.

2.2.2 RAC Air Samples

The RAC sample components were (1) sample Florisil cartridge (front and back), (2) deionized water impinger solutions, and (3) RAC train hexane washings. Seventeen RAC samples were analyzed using the routine Versar procedures. The front sections of the Florisil cartridges were placed in a soxhlet extractor and extracted for eight hours with 600 ml of hexane at six cycles/hour. The back sections were stored in glass vials. The impinger solutions (400 ml of deionized water) were transferred to 1 liter separatory funnels and the pH was measured and verified to between 5-9. The solutions were extracted three times with 50 ml portions of methylene chloride. All extracts were dried by passing through a column of anhydrous sodium sulfate and were combined with the RAC train washings. The combined extracts were then concentrated to 2 ml for column cleanup, as described in Section 2.3.2. The back Florisil was saved for analysis to detect breakthrough if the front section showed high concentrations. If PCBs had been detected in the front Florisil, the back Florisil would have been analyzed to determine if breakthrough occurred.

2.2.3 Probe Washings

Ten hexane probe washings were analyzed by concentrating the hexane to approximately 2 ml using Kuderna-Danish apparatus. The extracts were then subjected to column chromatography as outlined in Section 2.3.2.

2.2.4 Teflon Tubes

Fourteen teflon tube transfer lines from the RAC samplers were extracted by pouring three 50 ml portions of hexane through one end of the teflon tubes and collecting at the other end. The hexane extracts were visually examined, and one sample, background, duct A, was found to contain a small quantity of flyash. This sample was filtered through a funnel contining approximately 20 g of sodium sulfate. The extracts were then concentrated to about 2 ml in Kuderna-Danish evaporators. GC/EC analysis of the extracts showed gross chromatographic interference in the PCB-1254 region. For this reason, the extracts underwent column chromatography as described in Section 2.3.2.

2.2.5 Flyash

According to Dr. Frank Whitmore's instructions, several of the flyash samples as received were composited before analysis. As a result, six composite samples and two uncomposited samples were actually analyzed. Each composite sample was fabricated by mixing 50 g of four individual samples as listed in Table 4. The composite was then rolled on a ball mill for approximately one half hour.

One hundred grams of well mixed flyash were weighed out into a 500 ml beaker. The flyash was then slurried with approximately 300 ml of 1N HCl. After separation by centrifugation, the residual ash was washed with deionized water, filtered, and dried at room temperature overnight. The sample was then transferred to a soxhlet extractor and extracted for 8 hours with 600 ml of hexane. The extract was transferred to a Kuderna-Danish evaporator and concentrated to approximately 2 ml. The concentrate was then subjected to column chromatography as outlined in the following section.

2.3 Sample Cleanup

2.3.1 Oil Samples

Diluted oil samples were chromatographed on a column packed with 20 g Florisil and eluted with 200 ml petroleum ether. The eluate was concentrated to 10 ml and analyzed by packed column GC.

TABLE B-4

COMPOSITING OF FLYASH

Flyash Samples	Composite Name
FA 111	F-1
FA 112	F-1
FA 113	F-1
FA 114	F-1
FA 121	F-2
FA 122	F-2
FA 123	F-2
FA 124	F-2
FA 211	F-3
FA 212	F-3
FA 213	F-3
FA 214	F-3
FA 221	F-4
FA 222	F-4
FA 223	F-4
FA 224	F-4
FA 311	F-5
FA 312	F-5
FA 313	F-5
FA 314	F-5
FA 321	F-6
FA 322	F-6
FA 323	F-6
FA 324	F-6
FA 315	F-11
FA 325	F-12

2.3.2 All Other Extracts

All non-oil extracts used a more elaborate chromatographic procedure to remove components which interfered with the GC analysis of PCBs. This procedure is recommended by Lustenhower, Olie, and Hutzinger for the analysis of incinerator effluent for chlorinated dioxins and related compounds. Briefly, the extracts are chromatographed on a series of two columns: the first column contained four grams of silica gel loaded with 40% (wt/wt) sulfuric acid; the second column was layered with two grams of silica gel loaded with sodium hydroxide (33% 1N NaOH by weight), two grams of silver nitrate loaded silica gel (10% $AgNO_3$ by weight), and one gram silica gel. The acid column was eluted with 20 ml hexane. The eluate was collected, concentrated to 2 ml, and placed on the layered column. The second column was eluted with 40 ml hexane. The first 10 ml eluate were discarded, and the next 30 ml were collected and concentrated to two ml for analysis by capillary GC.

An elution study was performed before applying this procedure to samples. The study allowed optimization of eluent volumes and collection fractions to ensure elution of all PCBs with minimum collection of interfering components.

3.0 GAS CHROMATOGRAPHIC ANALYSIS

3.1 Packed Column GC

The oil feed samples were analyzed by routine methods using a packed GC column and electron capture detection. This is an EPA approved procedure used for the analysis of routine non-degraded PCB samples. The analytical conditions are listed in Table 5.

3.2 High Resolution GC

A capillary column, rather than the conventional packed column, was used to provide maximum separation and sensitivity for the identification and quantitation of PCB-1254 in the incinerator effluent samples (RAC samples, teflon tubing, probe washings, and flyash).

The column-cleaned extracts were analyzed on a high resolution gas chromatograph for PCB-1254. Two GCs were used: A Varian 3700 and an HP5880. Each system was optimized for performance. Separation was achieved on an OV-101 glass wall coated open tubular (WCOT) capillary column. Two-microliter injections were made in the split mode. The carrier gas was Matheson purity helium (99.9999%) at a flow rate of 0.6-0.7 ml/min. The make-up gas was optimized for individual detector response. The oven was operated isothermally to provide best peak separation. Analytical conditions are listed in Table 6. The two systems provided equivalent analysis.

3.3 Standard Versar Quality Control

All analyses and methods studies were carried out under the standard Versar Quality Control Program (SVQCP). The SVQCP is included with each batch of samples. (A batch is a suitable number of samples to be analyzed at one time.) The program consists of four QC audits which are treated with the same conditions as the samples. The QC audits represent 20-400% of the total number analyzed, depending on the number of samples per batch. The audits are:

(1) Duplicate Sample
(2) Spiked Matrix
(3) Method Standard
(4) Method Blank

TABLE B-5

GC/EC ANALYTICAL CONDITIONS

Gas Chromatograph	Varian 6000
Detector	Electron Capture
Column Dimensions	180 cm x 4 mm ID glass
Packing Materials	3% OV-1 on Gas Chrom Q (100/120)
Oven Temperature	200°C Isothermally
Injection Port Temperature	250°C
Detector Temperature	300°C
Carrier Gas	5% methane/argon
Flow Rate	30 ml/min.
Injection Volume	2 ul

TABLE B-6

CAPILLARY GC/EC ANALYTICAL CONDITIONS

Parameter	GC 1	HP 5880
Detector	Electron Capture	Electron Capture
Column Dimensions	25m x .1mm ID Glass	12m x .2mm ID Glass
Liquid Phase	OV-101 WCOT	OV-101 WCOT
Oven Temperature	200°C	180°C
Injection Port Temperature	250°C	250°C
Detector Temperature	300°C	300°C
Carrier Gas Flowrate	0.7 ml/min Helium	0.6 ml/min Helium
Make-up Gas Flowrate	18 ml/min Nitrogen	25 ml/min 5% CH_4/Ar
Injection Volume	2 ul	2 ul
Split Ratio	20:1	40:1

A sample is chosen randomly from the batch and split three ways, labelled x, y and z. The x and y aliquots are analyzed as duplicates (QC Audit 1). The z aliquot and a blank sample (QC Audits 2 and 3) are spiked with the parameter of interest at the concentration of interest. The fourth QC audit is simply a blank treated as a sample.

Versar calculates its laboratory precision and recovery as follows:

Precision - calculated from the duplicate sample and presented as the relative percent difference

$$RPD = \frac{a - b}{(a + b)/2} \times 100$$

Recovery - calculated from the spiked sample and the method standard and presented as the percent recovered

$$\% \text{ Recovery } \frac{c}{d} \times 100$$

Where: a - first value from sample "x"
b - second value from sample "y"
c - amount calculated
d - amount spiked

Method blanks are calculated from the values obtained from instrument background and method interferences detected during analysis. A "less than" value does not mean the parameter of interest was detected but rather it reflects the lower limit of detection.

Tests were performed on standard materials to determine the efficiency of the analytical methods presented in the previous section. The tests consisted of elution studies for the column cleanup procedure and extraction tests of the flyash. These method studies have been used to determine specific conditions required to quantitatively recover the species of interest. Elution studies were performed to verify that the required cleanup separation was adequate and that the materials used performed to the specifications of the method.

4.0 RESULTS AND DISCUSSION

The analytical results and detection limit for PCB Aroclor 1254 in each of the matrices are discussed below. Chromatograms of all samples are compiled in Appendix A.

4.1 Oil Samples

The analytical results for PCB-1254 in the feed oil are listed in Table 7. Good agreement was found among the three samples and the quantity of PCB is well above the detection limit of 1 ppm. The quality control results for this batch of samples are also listed in Table 7.

The concentration reported are determined as a weight: weight ratio. Since the oil feed rate for incineration was controlled by volume, the density of the oil is necessary for computation of PCB feed rate. The densities were determined based upon a 10 ml volume of oil and are reported in Table 8.

4.2 RAC Samples

The analytical results and batch QC for PCB-1254 collected by the RAC air samplers are listed in Table 9. The total PCB found is the sum of the PCB in the front Florisil compartment, the impinger solution, and the hexane washings of the RAC train. No PCBs were detected in these samples. A 0.1 ppm PCB-1254 standard chromatogram is shown in Figure 1 and is defined as the detection limit. A typical chromatogram is shown in Figure 2 of an impinger sample. The detection limit in the extract corresponds to a total PCB quantity of 0.2 ug per sample extracted.

4.3 Probe Washings

The results and QC for the PCB analysis in the probe washings are listed in Table 10. Only the probe washings of Box #5 were found to contain PCB-1254 above the detection limit of 0.2 ug per sample. This sample contained 0.33 ug 1254. The peaks present in the probe washing chromatogram were absent in the trace for the reagent blank, and clearly match the PCB standard shown in Figure 2. Non-PCB organics are also present in this probe washing. Since this probe was used in an

TABLE B-7

ANALYTICAL RESULTS AND QC FOR OIL SAMPLES

Results:

Sample	Concentration
7619	210 ppm
7620	220 ppm
7621	210 ppm

Batch QC Data:

Sample	Spike Level	Conc Found	% Recovery	Precision
7619A,B		202/209		3%
Spiked Sample	50 ppm	50.4	101%	
Method Standard	50 ppm	47.6	95%	
Reagent Blank		<1 ppm		

TABLE B-8

DENSITY OF OIL SAMPLES

Sample Number	Density	
	g/ml	kg/gal
7619	.8803	3.33
7620	.8732	3.31
7621	.8121	3.07

TABLE B-9

ANALYTICAL RESULTS AND QC FOR RAC SAMPLES

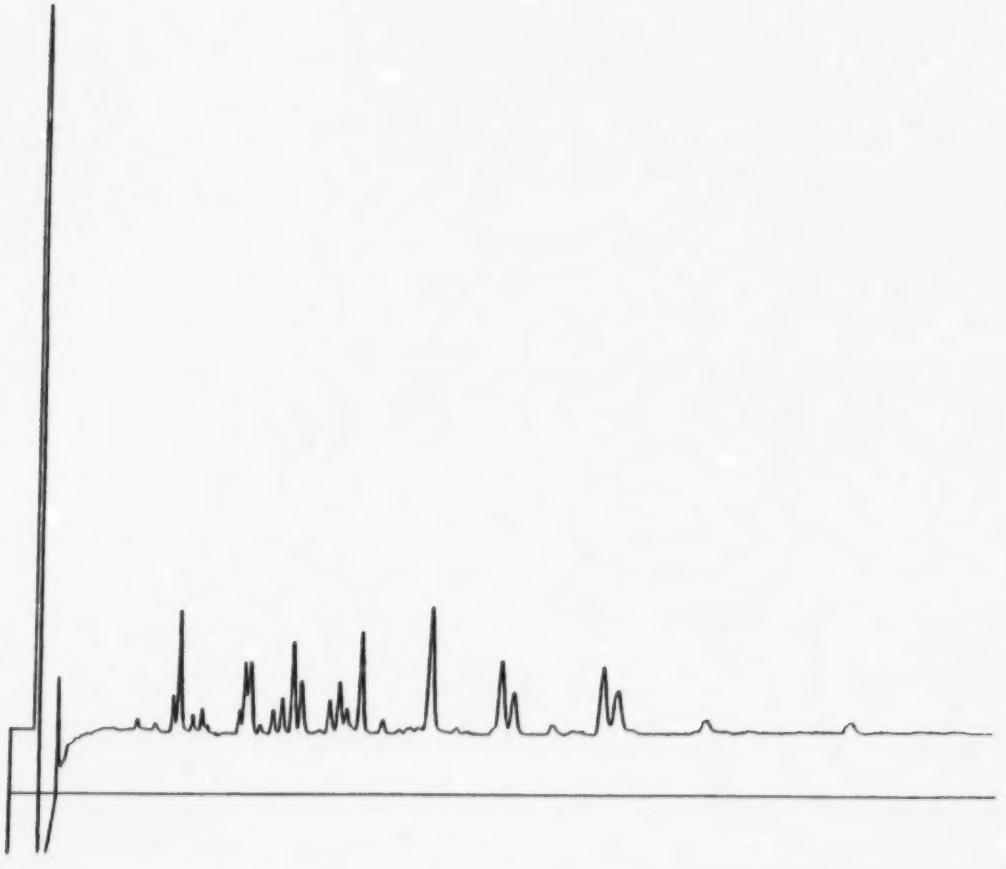
RESULTS:

	Sample Location	Laboratory Sample #	Total ug of PCB-1254
Box #1	Background duct A - up	7583	N.D.*
Box #2	Background duct B - up	7584	N.D.
Box #3	Exp.#1 A.M. - duct A down	7585	N.D.
Box #5	Exp.#1 A.M. - duct B down	7586	N.D.
Box #6	Control #1 A.M. 11/11/81	7587	N.D.
Box #7	Exp.#1 P.M. - duct A down	7588	N.D.
Box #8	Exp.#1 P.M. - duct B down	7589	N.D.
Box #10	Exp.#2 A.M. - duct B down	7590	N.D.
Box #11	Exp.#2 A.M. - duct A down	7591	N.D.
Box #12	Exp.#2 P.M. - duct A down	7592	N.D.
Box #13	Exp.#2 P.M. - duct B down	7593	N.D.
Box #14	Exp.#3 A.M. - duct A down	7594	N.D.
Box #15	Exp.#3 A.M. - duct B down	7595	N.D.
Box #16	Control #2 A.M. 11/13/81	7596	N.D.
Box #17	Exp.#3 P.M. - duct A down	7597	N.D.
Box #18	Exp.#3 P.M. - duct B down	7598	N.D.

*N.D. = Below detection limit of 0.2 ug/sample.

Batch QC Data:

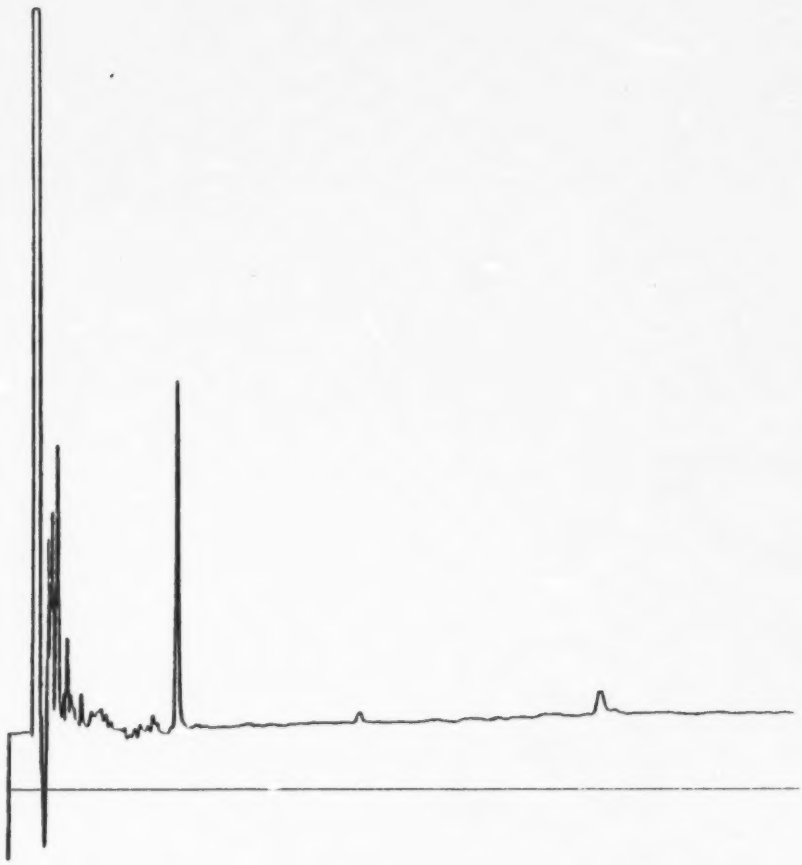
Sample	Spike Level	Conc.Found	% Recovery
Method Standard	1 ug	.78 ug	78%
Box #25 (Glassware Blank)		N.D.	
Reagent Blank		N.D.	



GC/EC Analytical Conditions

Gas Chromatograph	Varian 3700
Detector	Electron Capture
Column Dimensions	24m x 0.25m ID
Liquid Phase	OV-101
Oven Temperature	200°C Isothermally
Injection Port Temperature	250°C
Detector Temperature	300°C
Carrier Gas	0.7 ml/min Helium
Make-up Gas	18 ml/min Nitrogen
Injection Volume	2 ul
Attenuation	16
Split ratio	1:20

FIGURE B-1. PCB-1254 STANDARD 2ul INJECTION OF 0.1 ppm



GC/EC Analytical Conditions

Gas Chromatograph	Varian 3700
Detector	Electron Capture
Column Dimensions	24m x 0.25m ID
Liquid Phase	OV-101
Oven Temperature	200°C Isothermally
Injection Port Temperature	250°C
Detector Temperature	30C°C
Carrier Gas	0.7 ml/min Helium
Make-up Gas	18 ml/min Nitrogen
Injection Volume	2 ul
Attenuation	16
Split ratio	1:20

FIGURE B-2. TYPICAL CHROMATOGRAM OF IMPINGER SAMPLES

TABLE B-10

ANALYTICAL RESULTS AND QC FOR PROBE WASHINGS

RESULTS:

	Sample Location	Laboratory Sample #	Total ug of PCB-1254
Box #27	Probe Wash of Box #3	7600	N.D.
	Probe Wash of Box #5	7600	0.325
	Probe Wash of Box #8	7600	N.D.
Box #28	Probe Wash of Box #10	7601	N.D.
	Probe Wash of Box #11	7601	N.D.
	Probe Wash of Box #12	7601	N.D.
	Probe Wash of Box #13	7601	N.D.
Box #29	Probe Wash of Box #15	7602	N.D.
	Probe Wash of Box #17	7602	N.D.
	Probe Wash of Box #18	7602	N.D.

N.D. = Below quantitation limit of 0.2 ug/sample.

Batch QC Data:

Sample	Spike Level	Conc. Found	%Recovery
Method Standard	1 ug	.86 ug	86%
Reagent Blank		N.D.	

incinerator burn which did not use PCB-spiked oil it seems likely that any PCB-1254 present would be the result of possible contamination. The clean reagent blank chromatogram and absence of 1254 from other probe washings indicate that any contamination was a spurious event in the field or laboratory.

4.4 Teflon Tubes

All of the teflon tubes were extracted and cleaned as outlined in Sections 2.2.4 and 2.3.2 of this report. Only the teflon tube from Box #17 was analyzed by gas chromatography. This sample contained no PCB-1254 above the quantitation limit of 0.2 ug per sample.

4.5 Flyash Samples

Method development for the analysis of flyash included a recovery study to evaluate the method, which was outlined in Sections 2.2.5 and 2.3.2. Five 50g samples of flyash #121 were spiked with 1.0 ug Aroclor 1254 and allowed to equilibrate for 2 hours. The spiked samples were then soxhlet extracted for eight hours and concentrated to approximately 2 ml. The extracts were then subjected to column cleanup and analyzed by capillary gas chromatography. The results listed in Table 11 show an average recovery of 55%.

The results for the analysis of the flyash samples are listed in Table 12. Only the spiked sample contained any Aroclor 1254 above the quantitation limit of 2 ppb. Most of the samples did show an Aroclor 1254 "fingerprint" pattern which was below the quantitation limit of 2 ppb. A typical chromatogram of the flyash samples is presented in Figure 3, which should be compared with the flyash standard chromatogram on Figure 4. One sample, F-11, was spiked with 0.5 ug Aroclor 1254 to give a final concentration of 5 ppb in the flyash. The recovery as shown in Table 12 was 46% and is consistent with the recovery found in the earlier recovery study.

TABLE B-11

RESULTS OF RECOVERY STUDY

SAMPLE #	SPIKE LEVEL	AMOUNT FOUND	% RECOVERY
FA #1	1.0 ug	.47 ug	47
FA #2	1.0 ug	.53 ug	53
FA #3	1.0 ug	.52 ug	52
FA #4	1.0 ug	.34 ug	34
FA #5	1.0 ug	.90 ug	90

Average = 55%

TABLE B-12

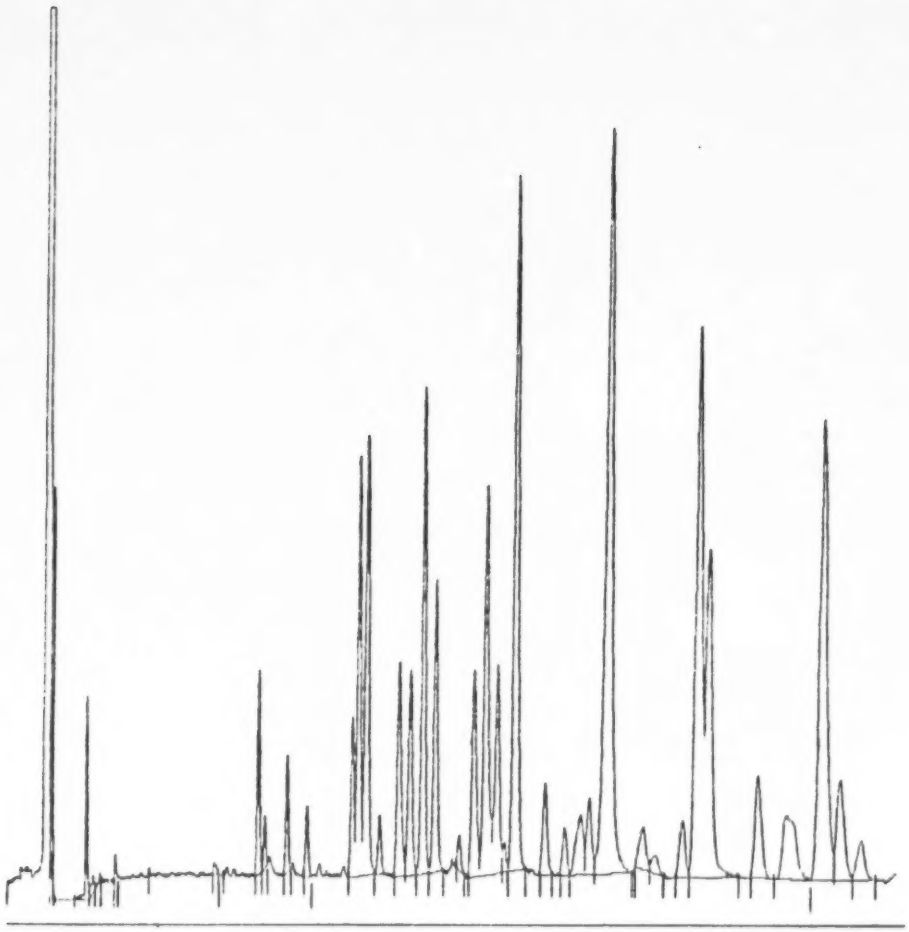
ANALYTICAL RESULTS AND QC FOR FLYASH SAMPLES

RESULTS:

SAMPLE#	ug of Aroclor 1254	Concentration (ng/g)
F-1	<0.2	<2
F-2	<0.2	<2
F-3	<0.2	<2
F-4	<0.2	<2
F-5	<0.2	<2
F-6	<0.2	<2
F-12	<0.2	<2
F-11	<0.2	<2
F-11 Duplicate	<0.2	<2

Batch QC Data:

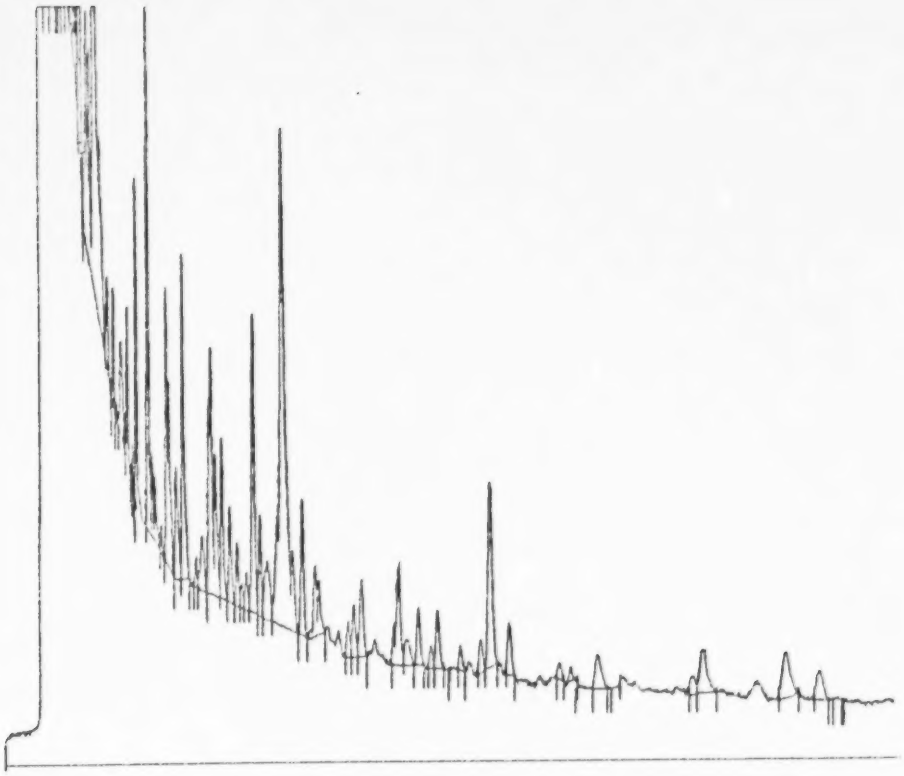
Sample	Spike Level	Amount Found	% Recovery
F-11 Spiked	0.5 ug	0.23 ug	46%
Method Standard	0.5 ug	0.28 ug	56%
F-11 Duplicates		<2 ppb/<2ppb	
Reagent Blank		0.07 ug	



GC/EC Analytical Conditons

Gas Chromatograph	Varian 3700
Detector	Electron Capture
Column Dimensions	24m x 0.25m ID
Liquid Phase	OV-101
Oven Temperature	200°C Isothermally
Injection Port Temperature	250°C
Detector Temperature	300°C
Carrier Gas	0.7 ml/min Helium
Make-up Gas	18 ml/min Nitrogen
Injection Volume	2 ul
Attenuation	16
Split ratio	1:20

FIGURE B-3. **FLY ASH STANDARD 0.5ppm 1254**



GC/EC Analytical Conditions

Gas Chromatograph	Varian 3700
Detector	Electron Capture
Column Dimensions	24m x 0.25m ID
Liquid Phase	OV-101
Oven Temperature	200°C Isothermally
Injection Port Temperature	250°C
Detector Temperature	300°C
Carrier Gas	0.7 ml/min Helium
Make-up Gas	18 ml/min Nitrogen
Injection Volume	2 ul
Attenuation	16
Split ratio	1:20

FIGURE B-4. **FLY ASH SAMPLE # 315Y**

4.6 Miscellaneous Determination: Thimble and Filter Weight

The total weight of flyash contained in two ceramic filters, samples F-101 and F-102, was determined. Also, the RAC sample filters used in Boxes #1 and #2 were weighed. These results are listed in Table 13.

TABLE B-13

RESULTS FOR DETERMINATION OF FLYASH AND FILTER WEIGHTS

SAMPLE #	WEIGHT
F101	9.915g ash in thimble
F102	7.830g ash in thimble
Box #1 Filter	0.255g
Box #2 Filter	0.211g

APPENDIX C

BUNKER SAMPLE PERIOD
STEAM PLANT OPERATING STATISTICS

Widows Creek Steam Plant
November 8-15, 1981

PERIOD HOURS 192:00

	Item No.		Unit 1
Generation	1	Average Hourly Gross Load, Kw	98626
	2	Maximum Hour Net Generation, Mwh	135
	3	Gross Generation, Mwh	14210
	4	Station Use, Mwh	836
	5	Net Generation, Mwh	13374
	6	Station Use, %	5.88
Factors & Use	7	Capacity Factor, %	52.6
	8	Turbo-Gen. Avail. Factor, %	100.0
	9	Boiler Avail. Factor, %	100.0
	10	Unit Avail. Factor, %	100.0
	11	Hours of Use	144.05
	12	Turbine Startups	1
	13	Boiler Cold Startups	1
Efficiency	14	Gross Heat Rate, Btu/Kwh	9850
	15	Net Heat Rate, Btu/Kwh	10460
	16	Boiler Efficiency, %	87.0
	17	Moisture in Fuel Loss, %	0.6
	18	Hydrogen Loss, %	3.6
	19	Dry Gas Loss, %	6.0
	20	Combustible Loss in Fly Ash, %	2.3
	21	Pyrite Loss, %	0.1
	22	Fixed Losses, %	0.4
	23	Total Losses, %	13.0
Temp. & Press.	24	Throttle Pressure, Psig	1475
	25	Throttle Temperature, °F	998
	26	Interceptor Valve Temperature, °F	--
	27	Exhaust Pressure, In. Hg. Abs.	1.19
	28	Intake Water Temperature, °F	61
	29	Air Temp. Ent. Air Htrs., °F-Avg.	98
	30	Gas Temp. Lvg. Air Htrs., °F-Avg.	308
	31	Dry Gas Loss Air Temp., °F	55

Flows	32	Throttle or Feedwater, M Lbs.	116946
	33	Superheat Attemperation, %	2.10
	34	Reheat Attemperation, %	--
	35	Makeup, %	1.43
	36	Building Heating Steam, %	--
Misc.	37	Total Air at Boiler Outlet, %	117
	38	Total Air at Air Heater Outlet, %	127
	39	Coal Fired, M Lbs.	11603.5
	40	Combustibles in Fly Ash, %	13.9